

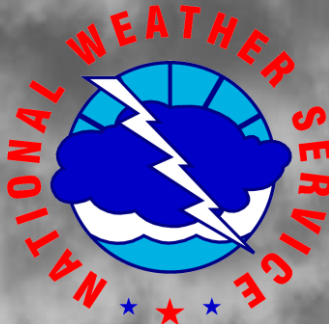
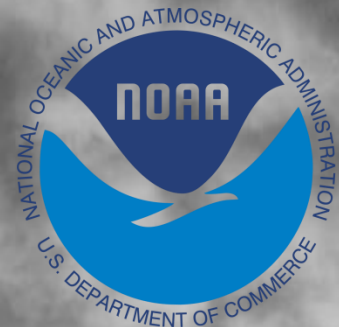
SKYWARN ADVANCED Storm Spotter Training



**Gerald Satterwhite
Meteorologist**



**U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
National Weather Service (NWS) – Calera, AL**



Welcome to **Advanced Spotter Training**

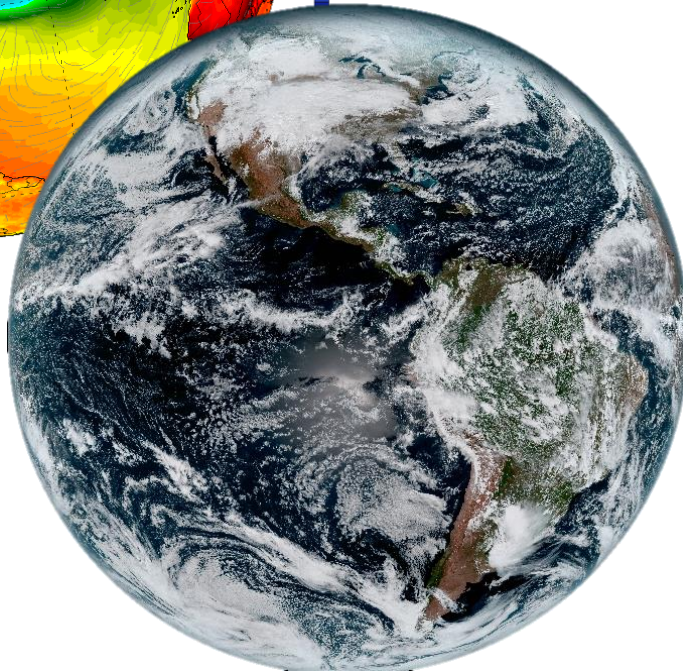
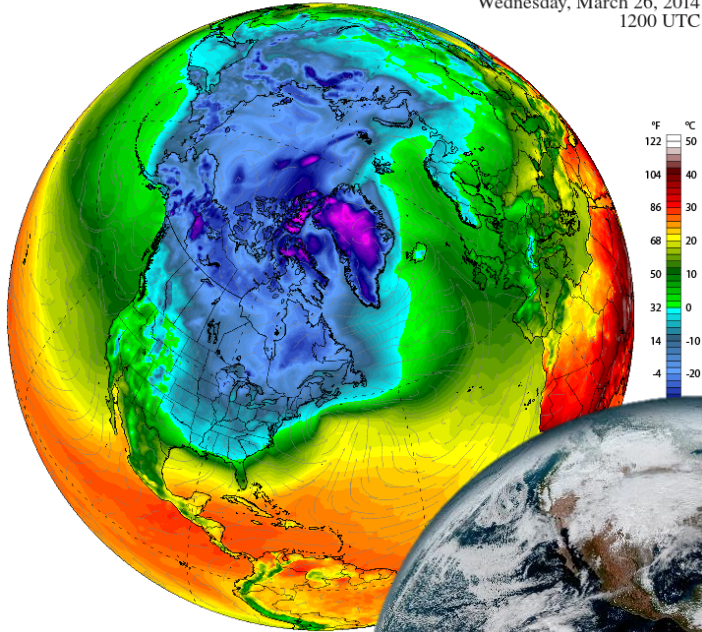
We'll take an in-depth look at:

- Development processes and ingredients
 - Severe thunderstorm forecasting
- Inspecting radar and satellite imagery

The Atmosphere

Global Forecast System Model

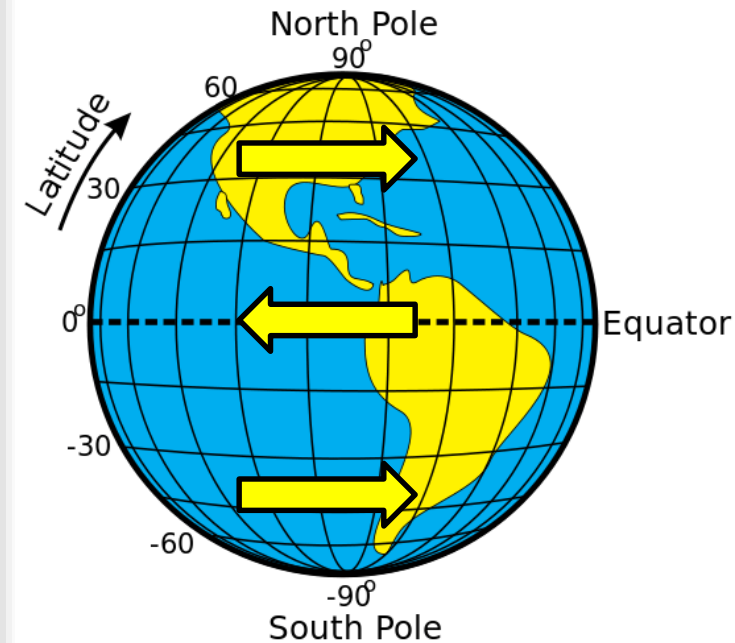
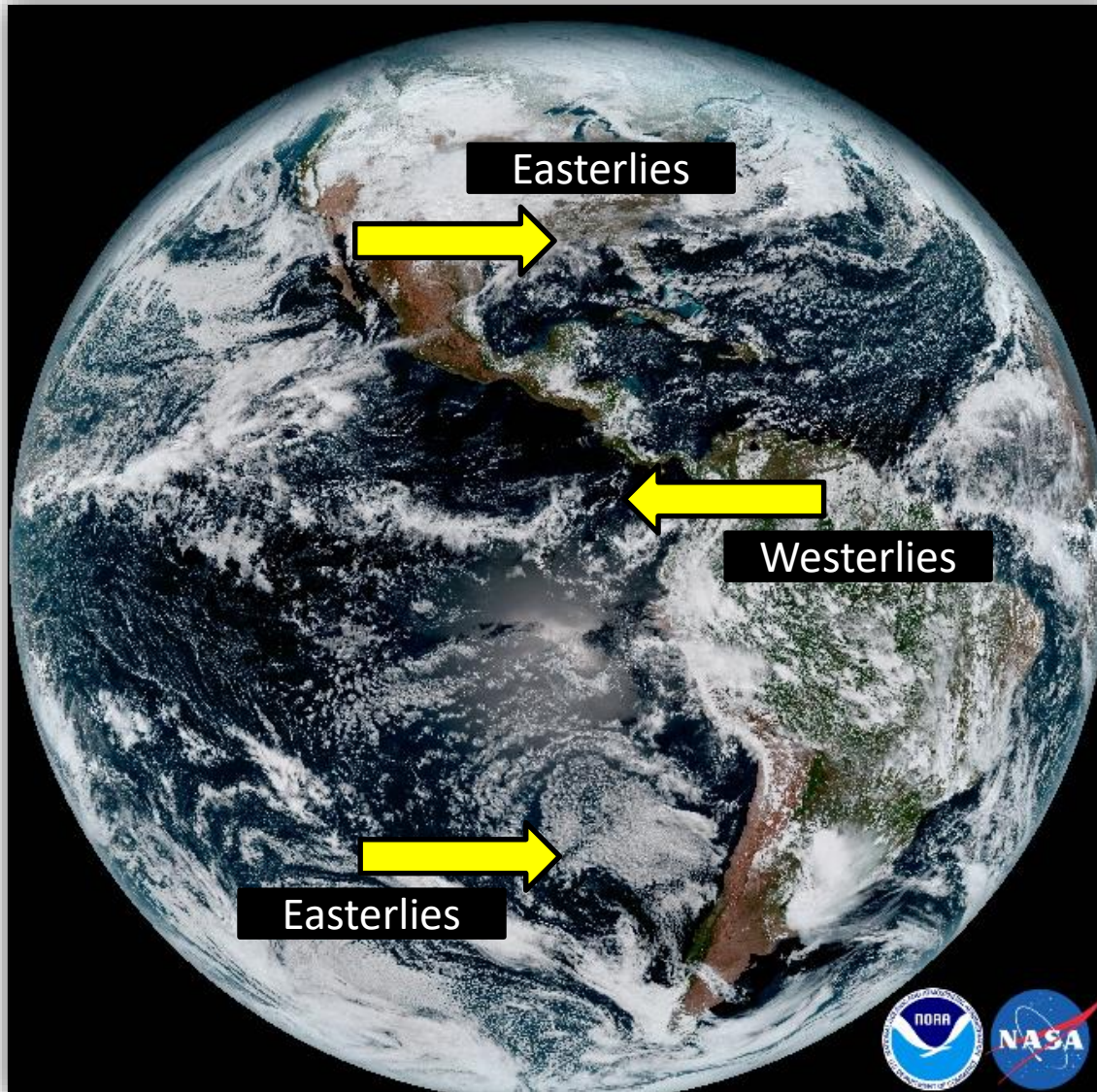
Temperature at 2 meters
Wednesday, March 26, 2014
1200 UTC



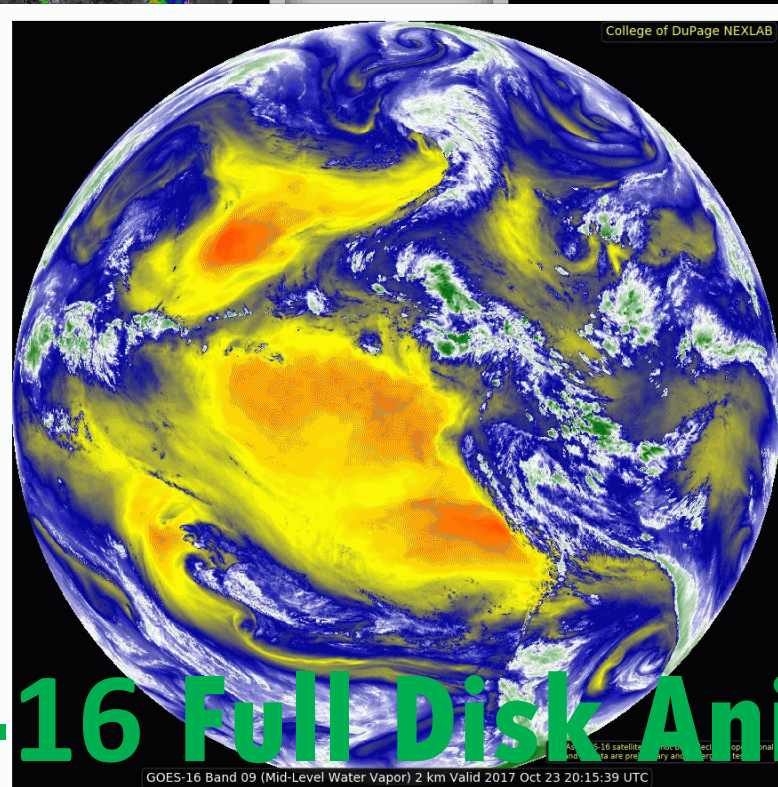
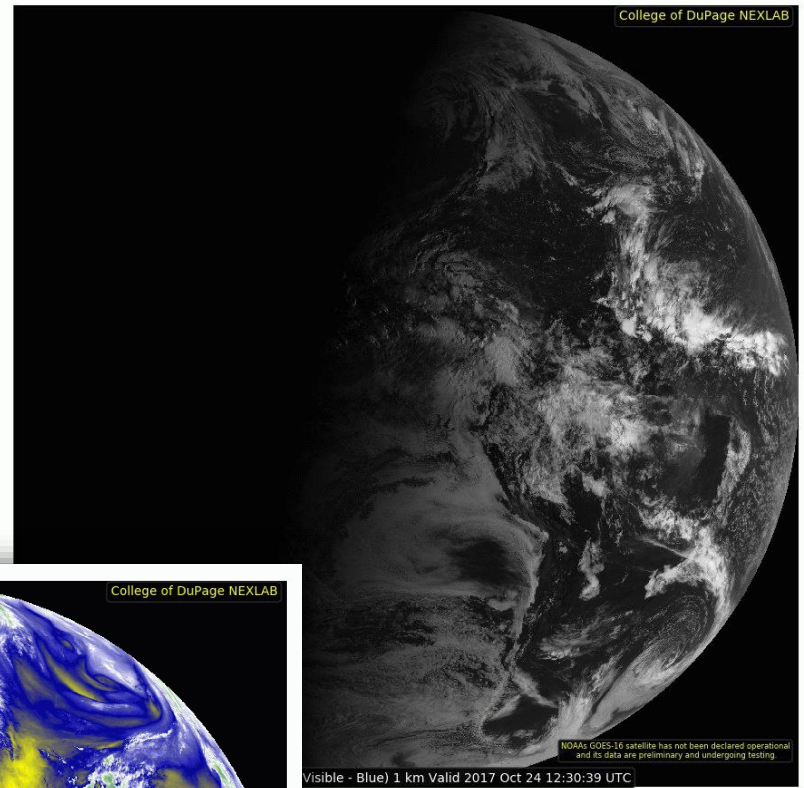
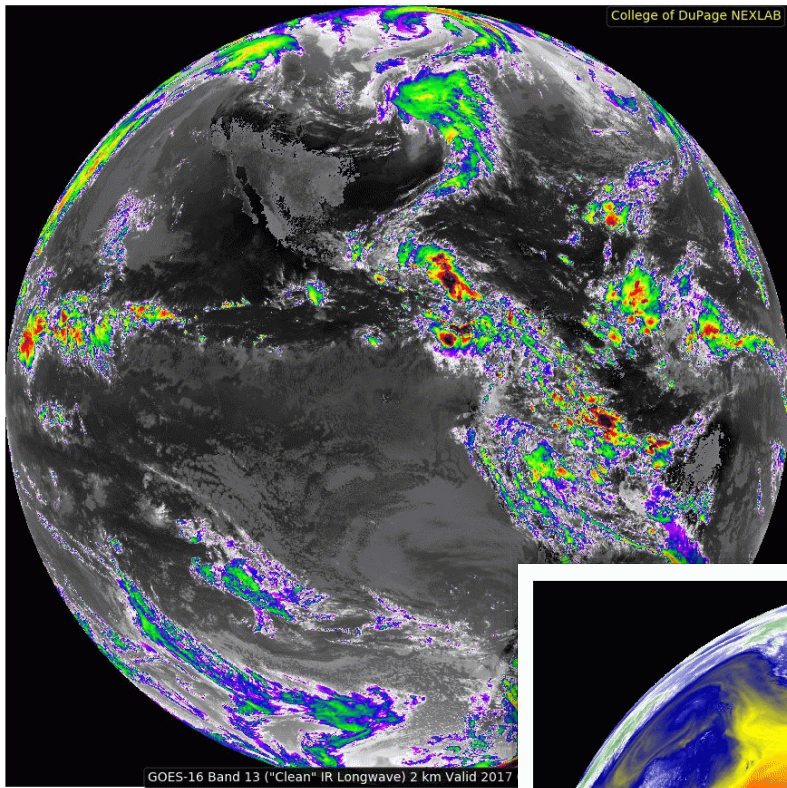
Large to Small Scale

- Global (Largest)
- Synoptic (Large)
- Mesoscale (Small)

Global Weather Patterns



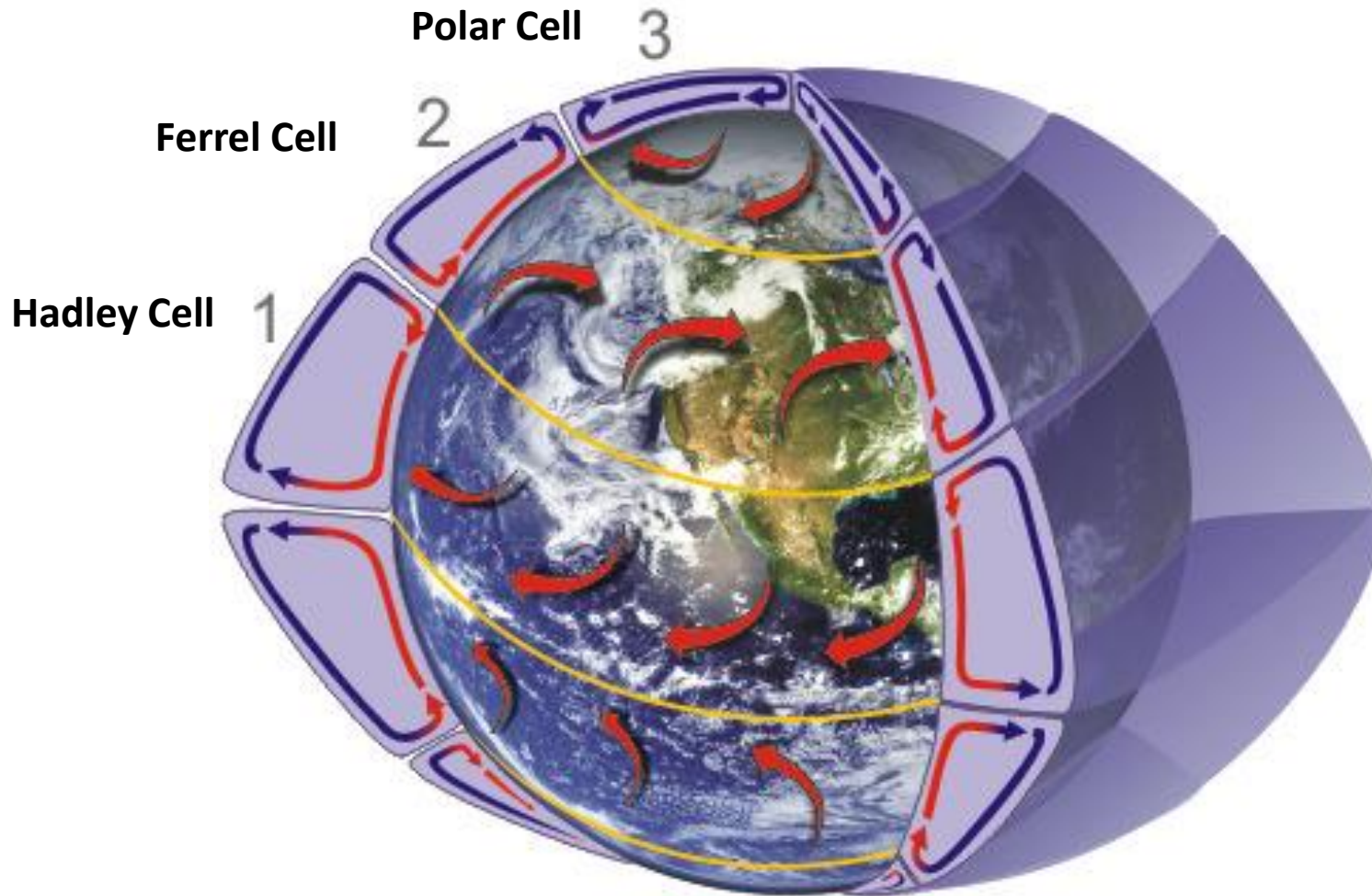
The sun drives the weather!



GOES-16 Full Disk Animation

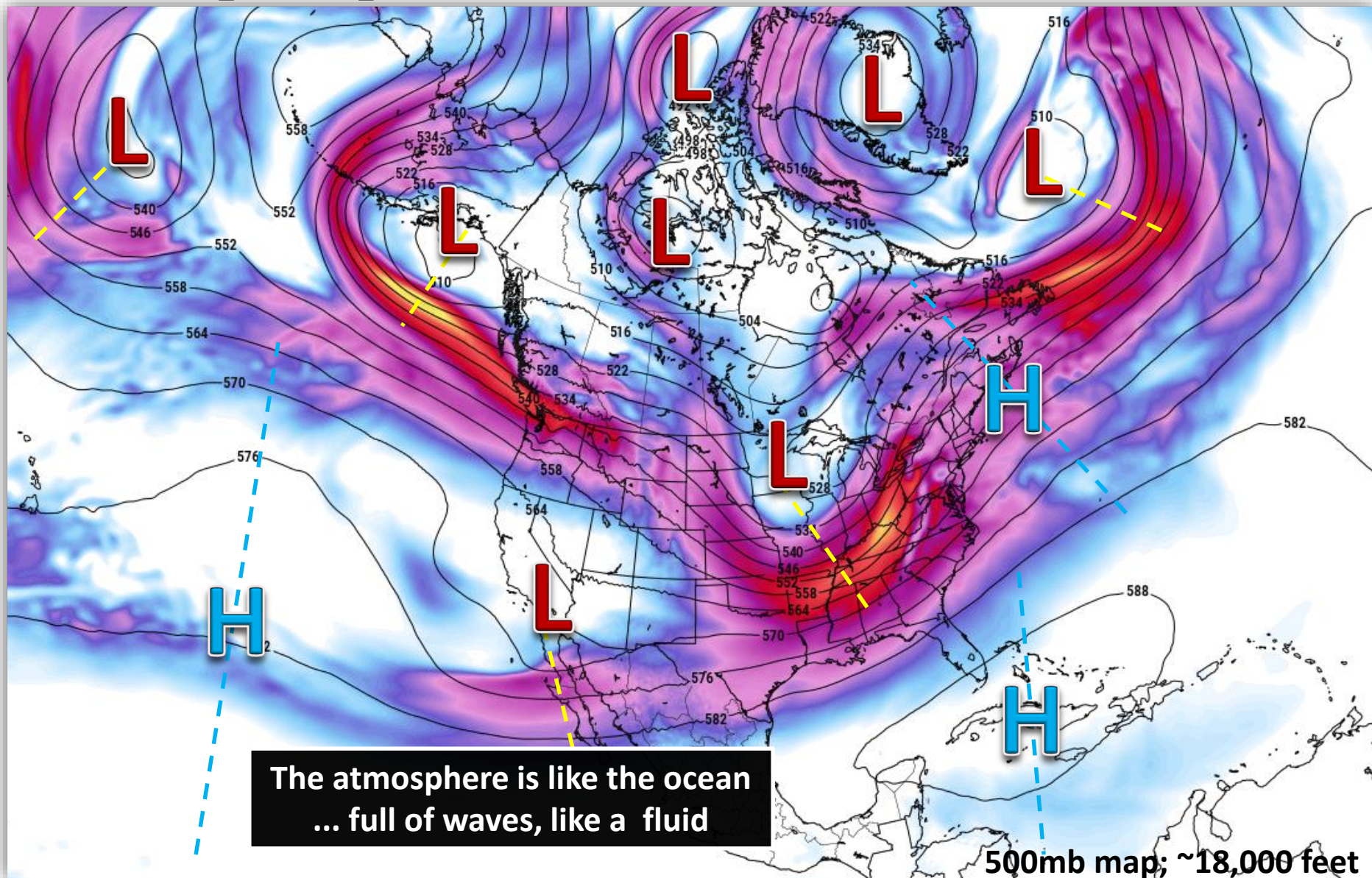


Global Circulations



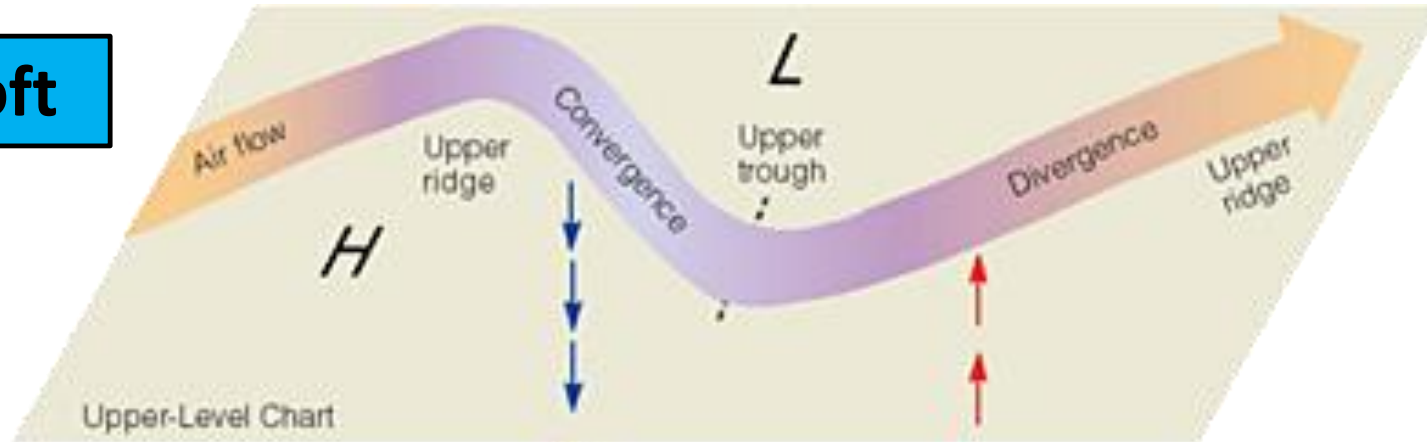
Over the major parts of the Earth's surface there are large-scale wind circulations present. The global circulation can be described as the world-wide system of winds by which the necessary transport of heat from tropical to polar latitudes is accomplished. –Met Office

Synoptic Weather Patterns

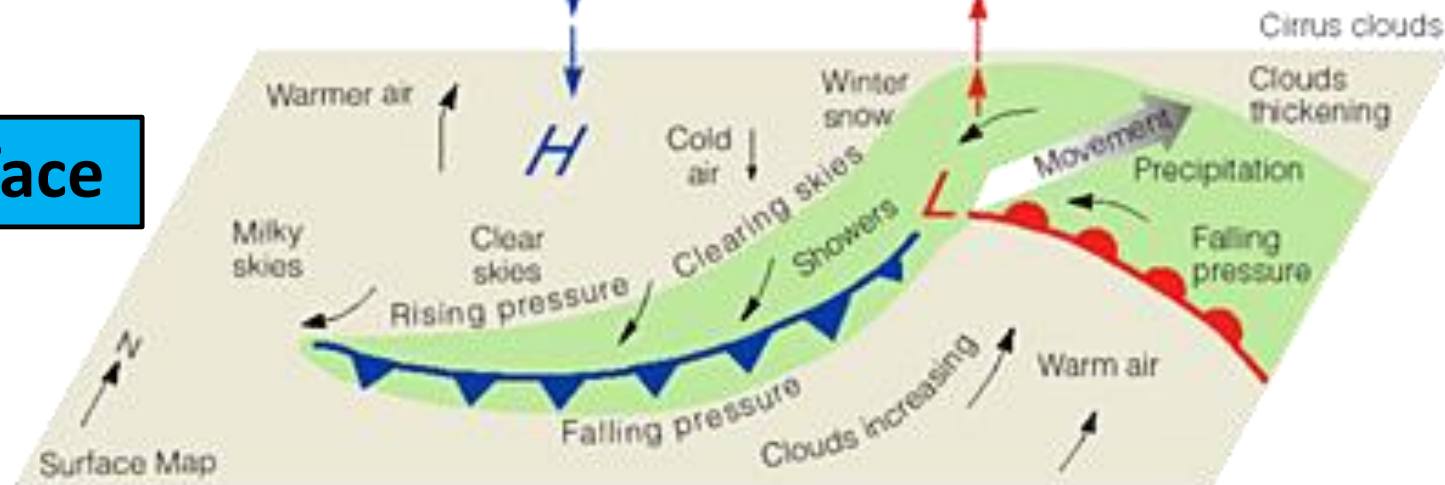


Synoptic Weather Patterns: Top-down

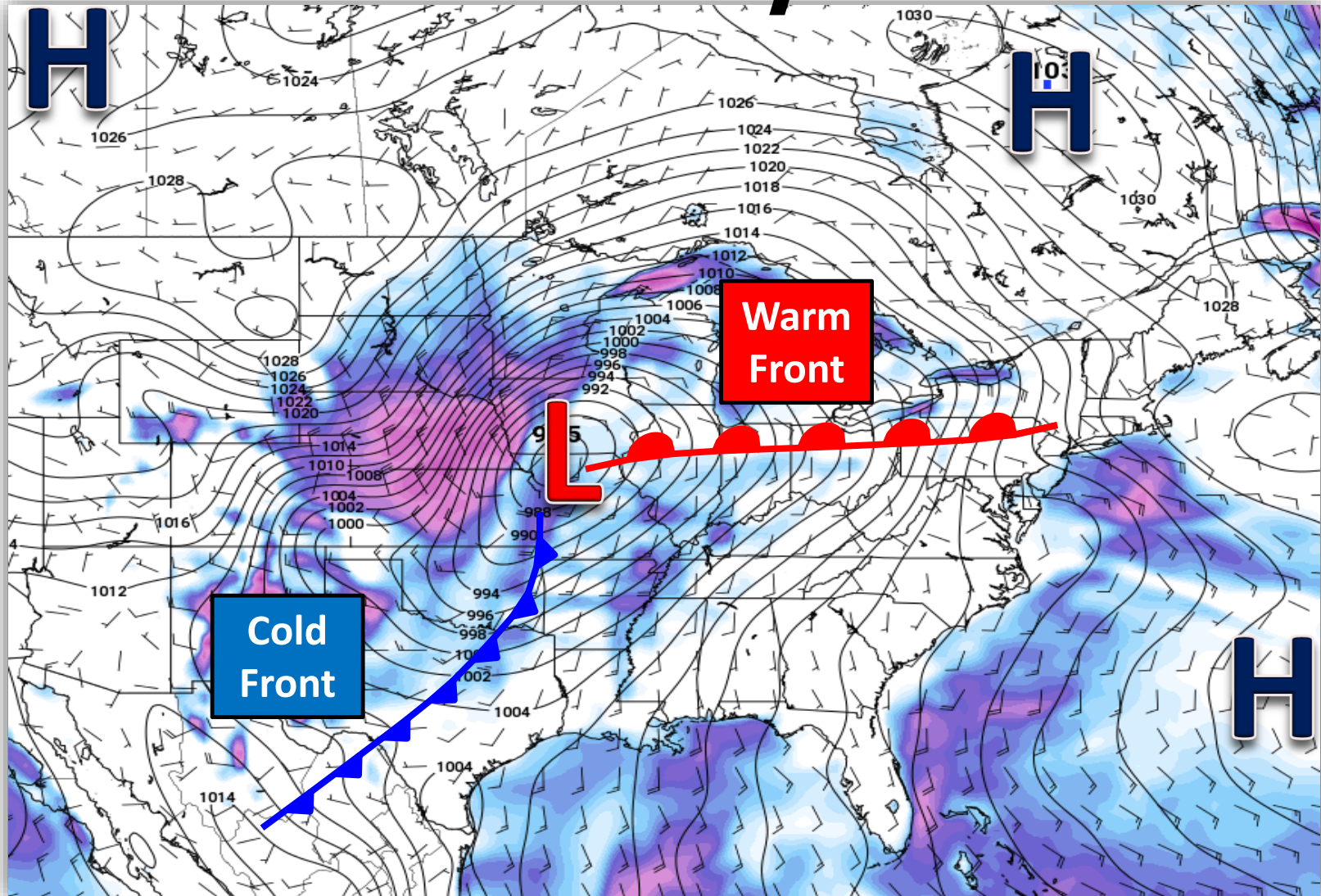
Aloft



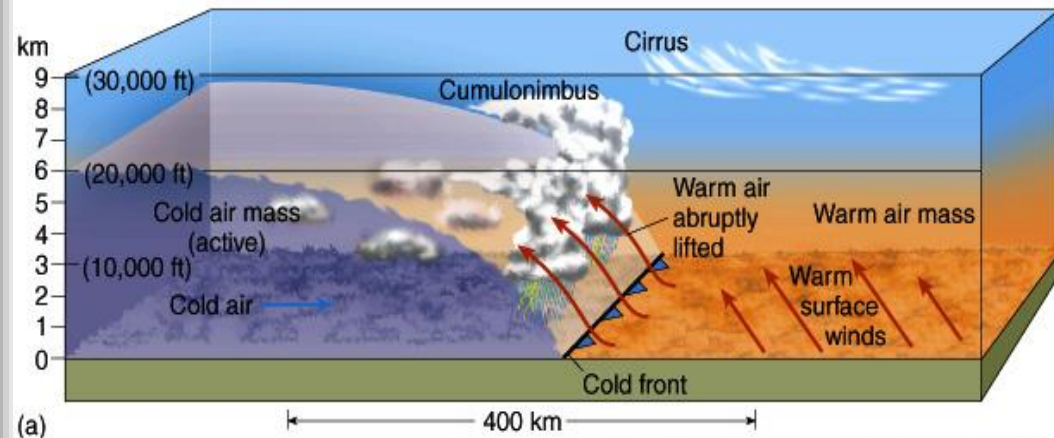
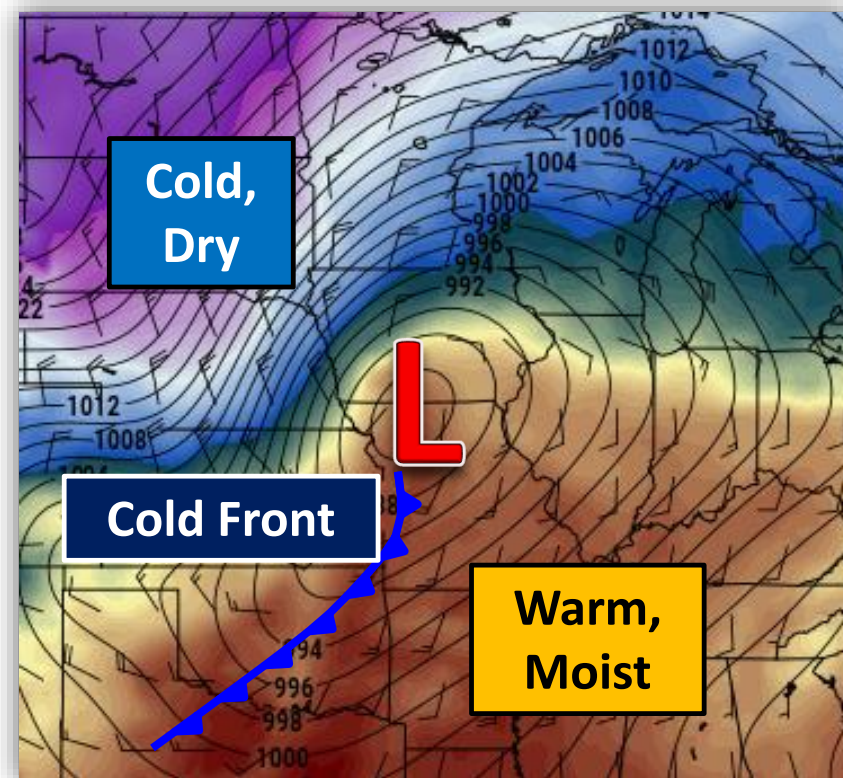
Surface



Synoptic Weather Pattern: Low Pressure System

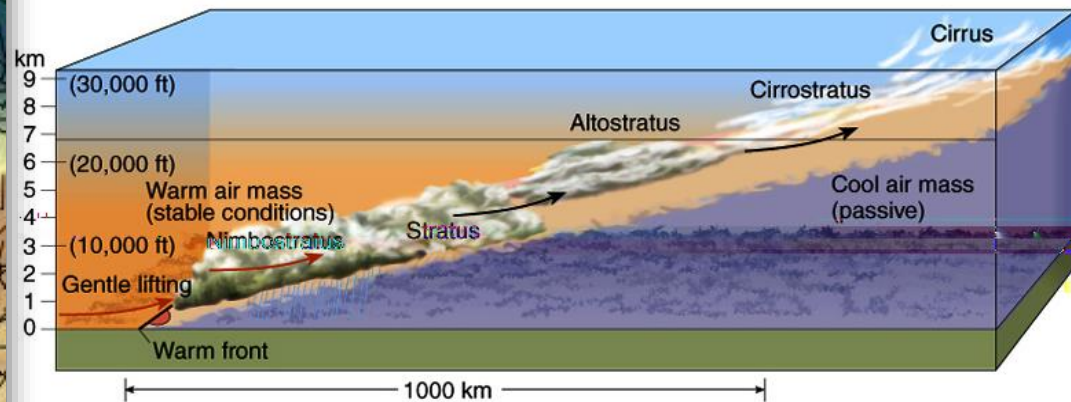
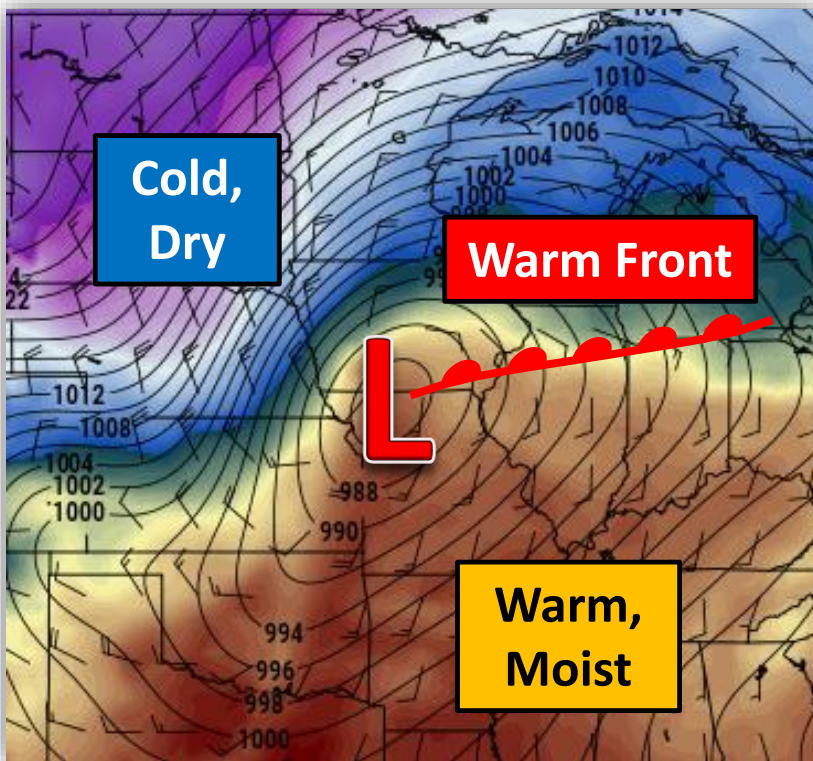


Synoptic Weather Pattern: Low Pressure System, Cold Front



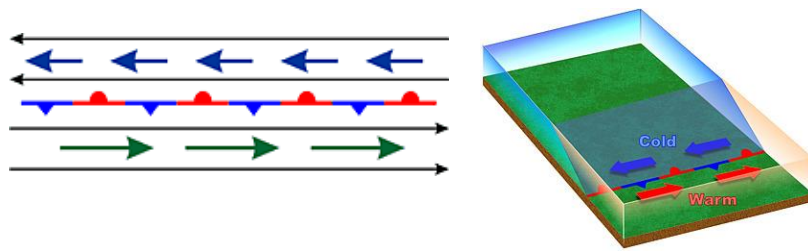
Cold front definition: A zone separating two air masses, of which the cooler, denser mass is advancing and replacing the warmer

Synoptic Weather Pattern: Low Pressure System, Warm Front

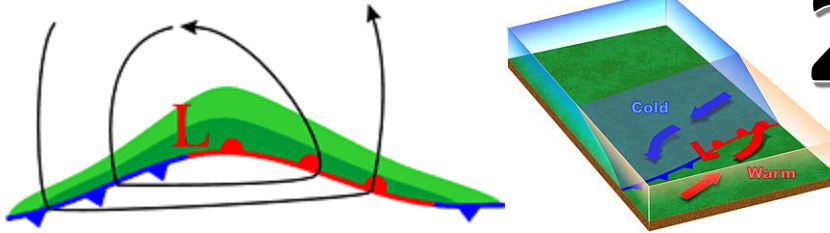


Warm front definition: A transition zone between a mass of warm air and the colder air it is replacing

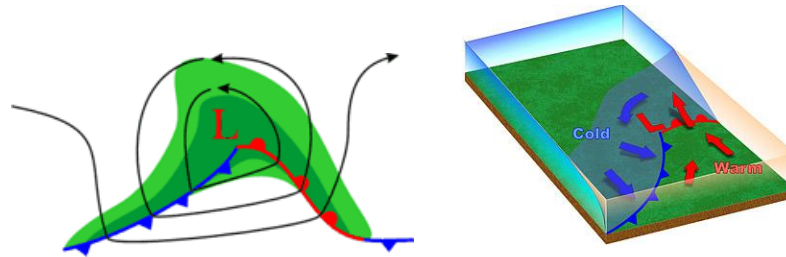
1 Boundary between warm, cooler air



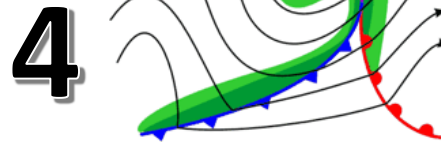
2 With upper-level impulse, surface wave forms; precipitation develops



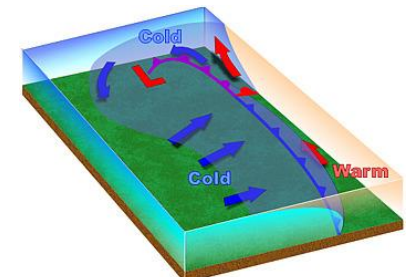
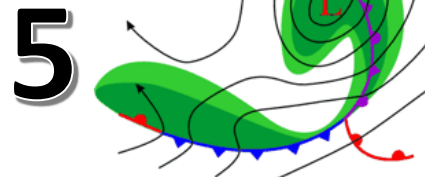
3 Wave intensifies, fronts become better organized

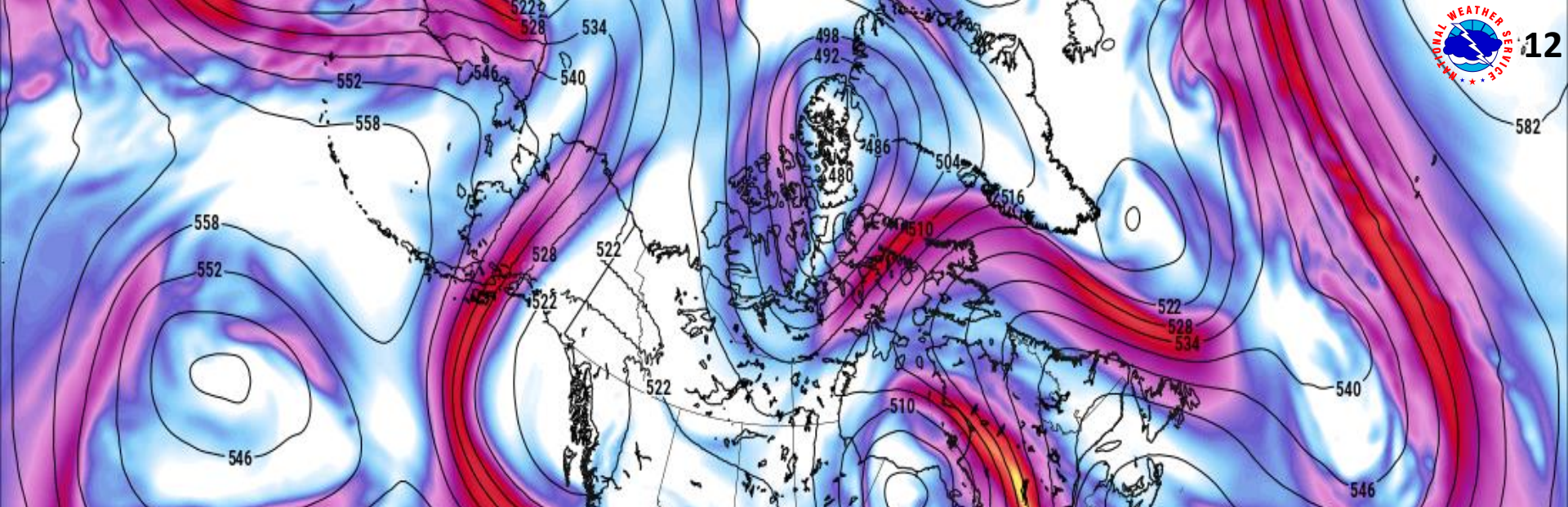


Low pressure matures. Cold front overtakes warm front and forms an occluded front

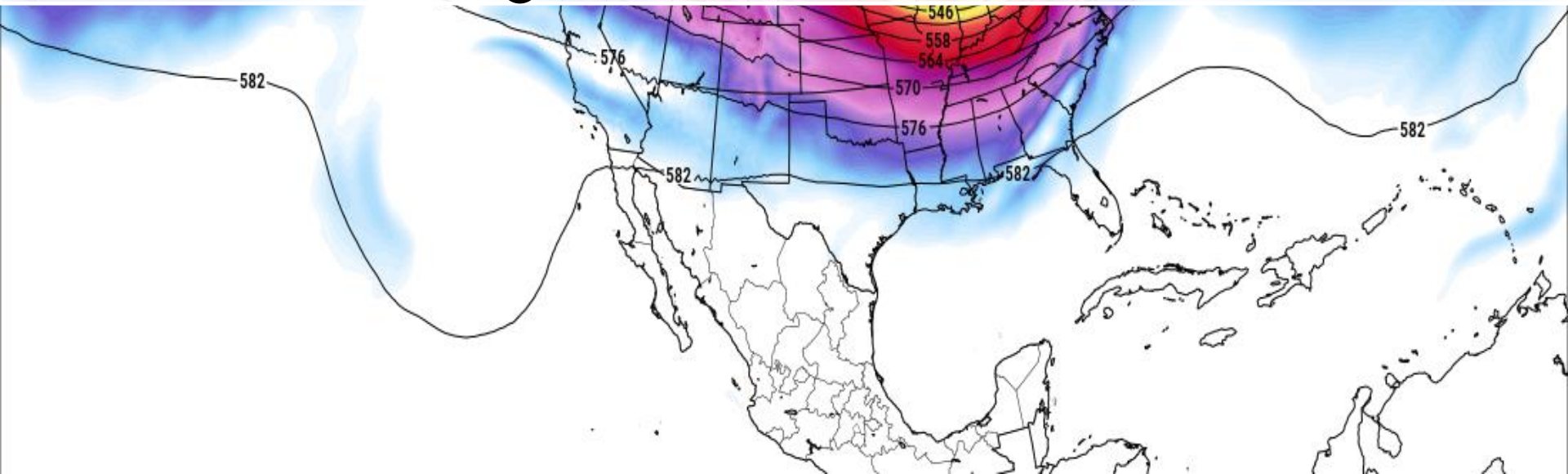


Cold front continues to advance on warm front and eventually cuts off supply of warm, moist air. Low pressure gradually dissipates

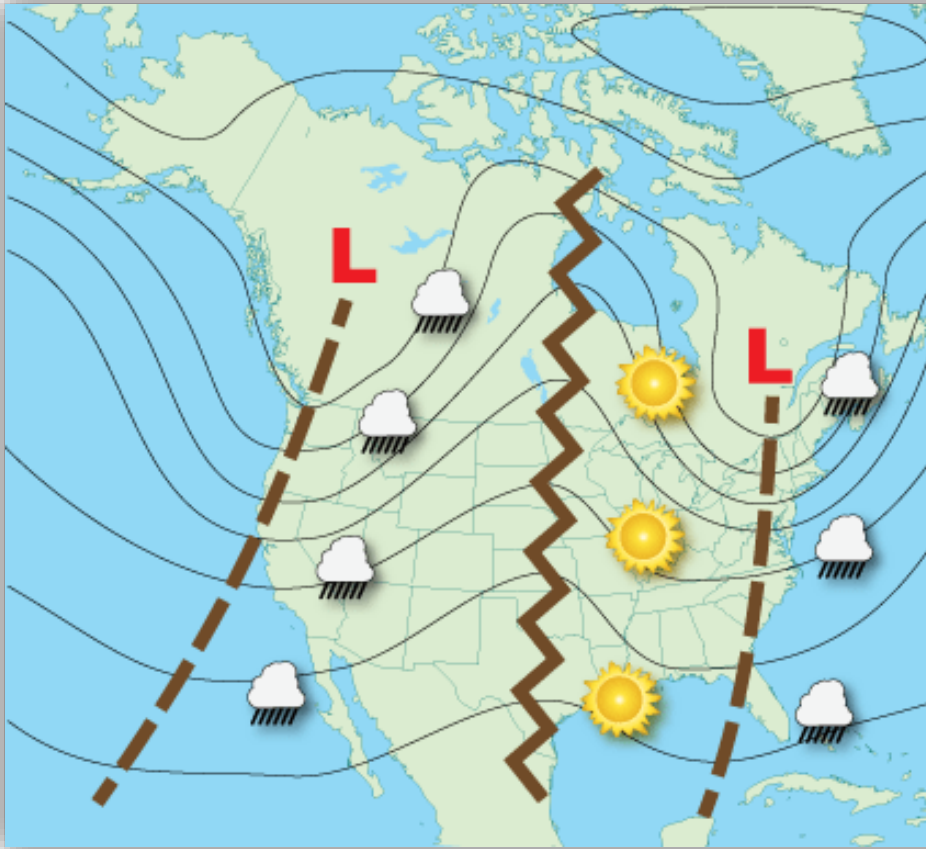




Synoptic Weather Pattern Types: Ridges, Troughs, and Cut-off Lows

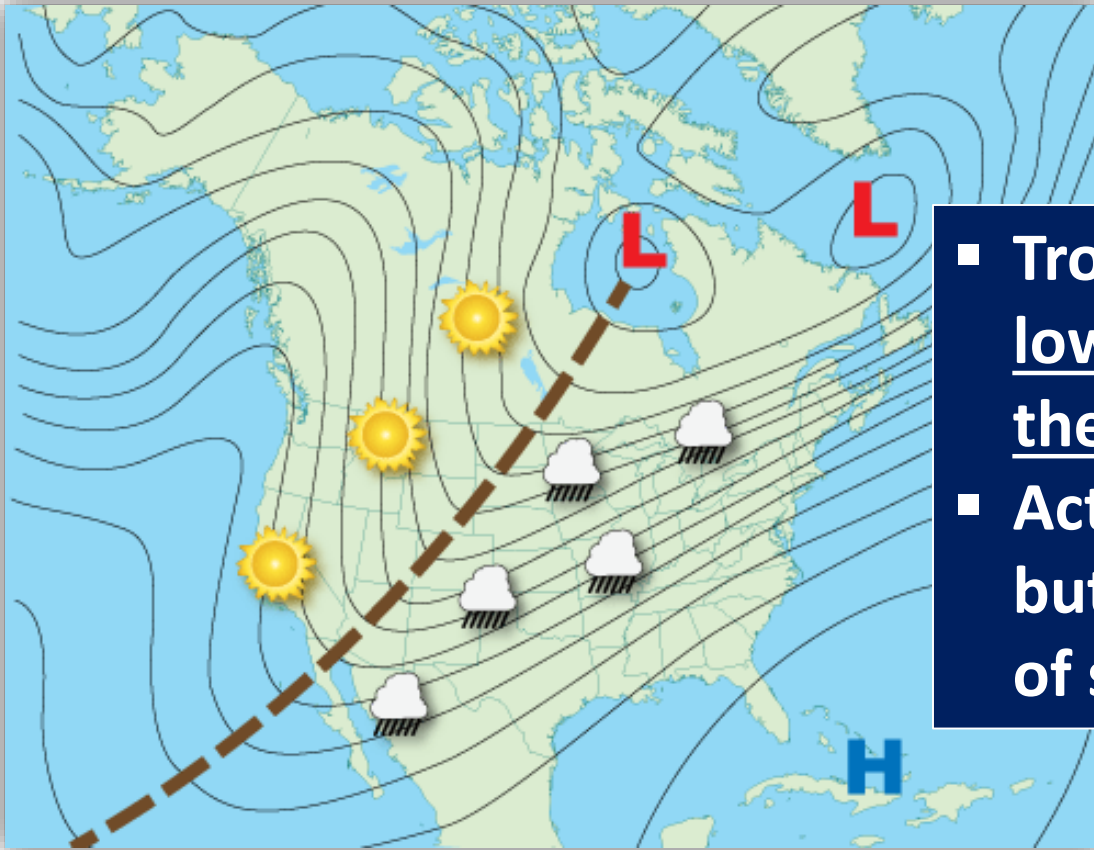


Neutrally-Tilted Troughs



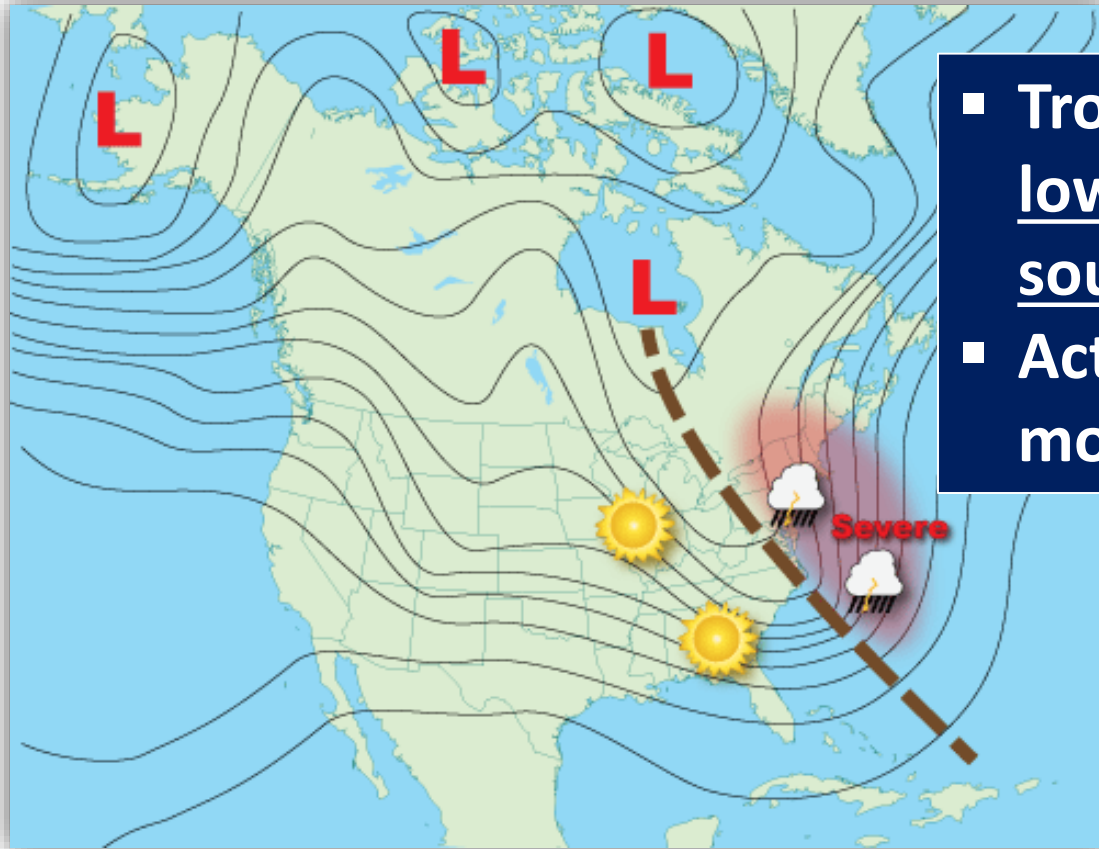
- Trough axis extends from the lowest pressure north to south
- The most common weather pattern
- Active weather occurs between the trough and downwind (eastward) ridge
- Fair weather occurs within and between the downwind trough

Positively-Tilted Troughs



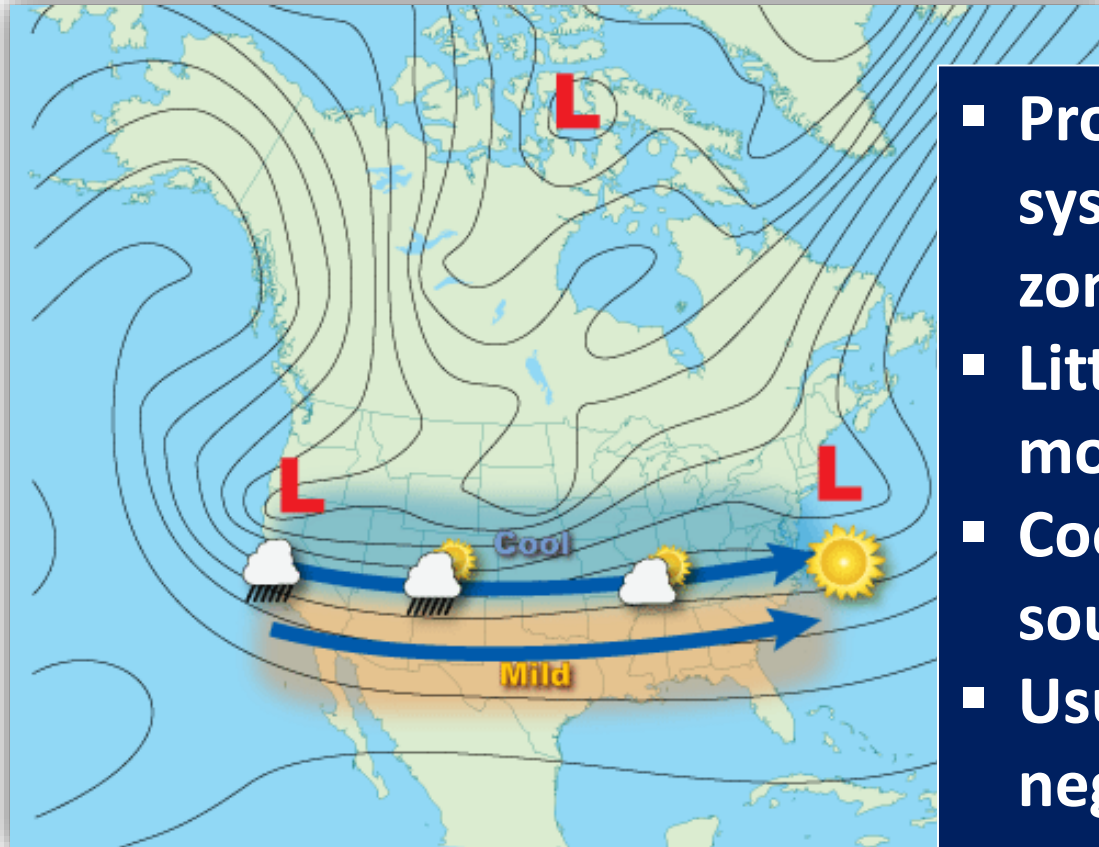
- Trough axis extends from the lowest pressure northeast to the southwest
- Active weather can occur, but not too much in the way of severe storms

Negatively-Tilted Troughs



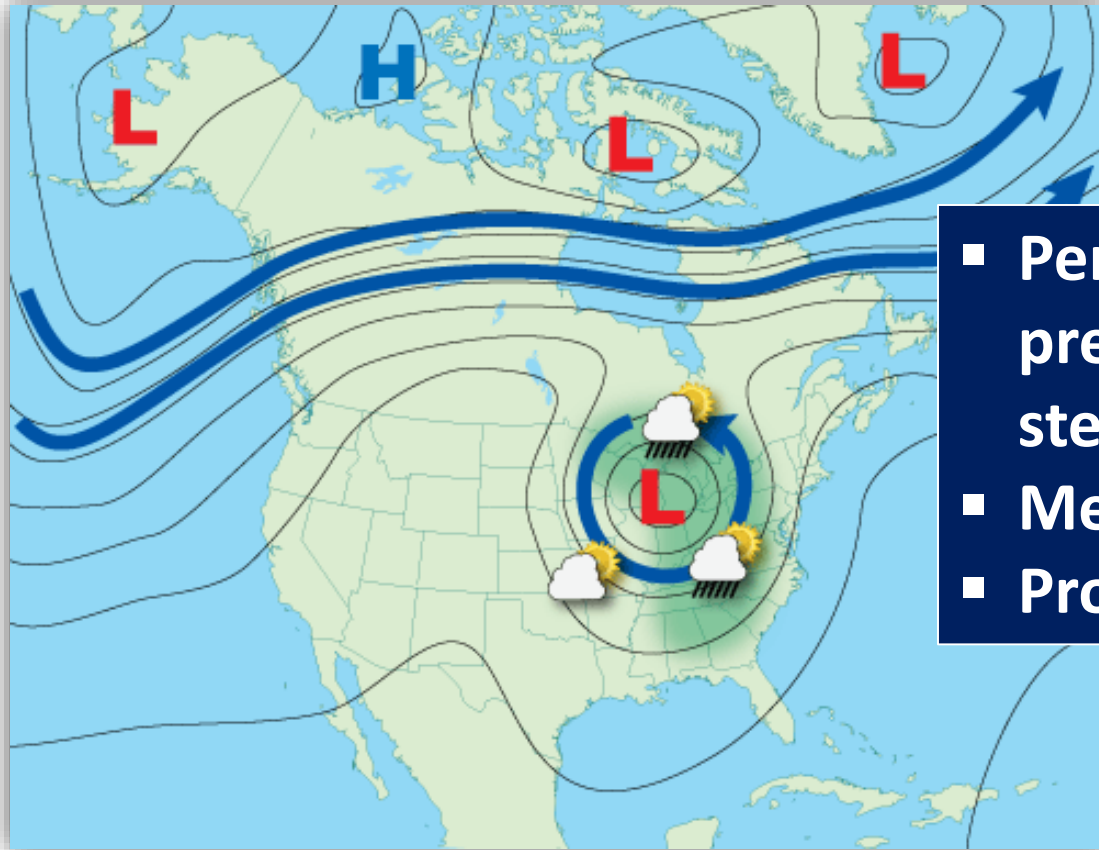
- Trough axis extends from the lowest pressure northwest to southeast
- Active weather with the most severe potential

Zonal (west to east) Flow



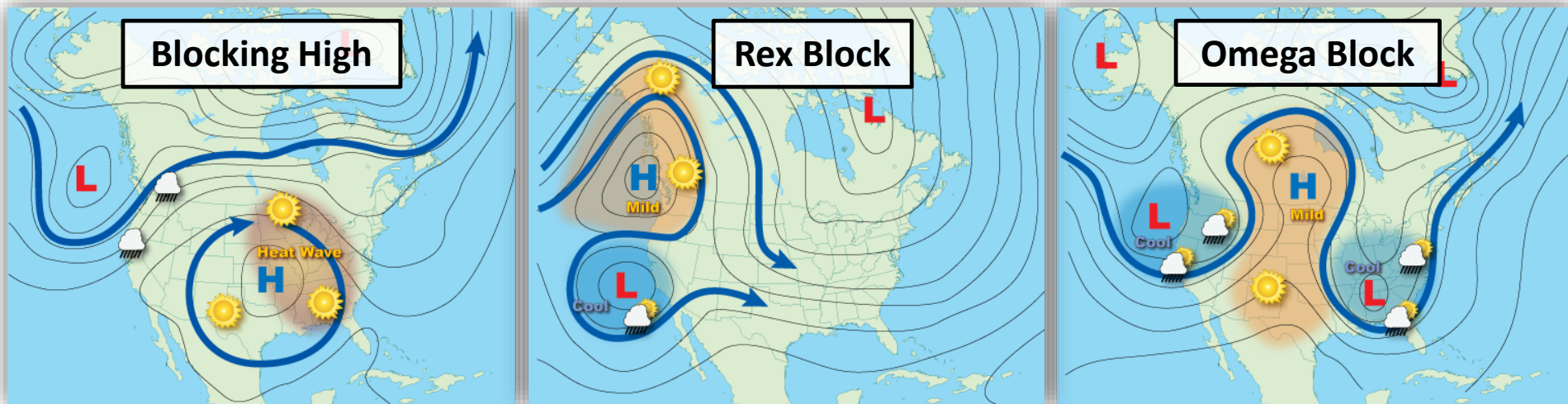
- Progressive motion of storm systems west to east along zonal axis
- Little north or south movement
- Cooler air north, warmer south
- Usually a positively- and negatively-tilted trough at each end

Cut-off Low



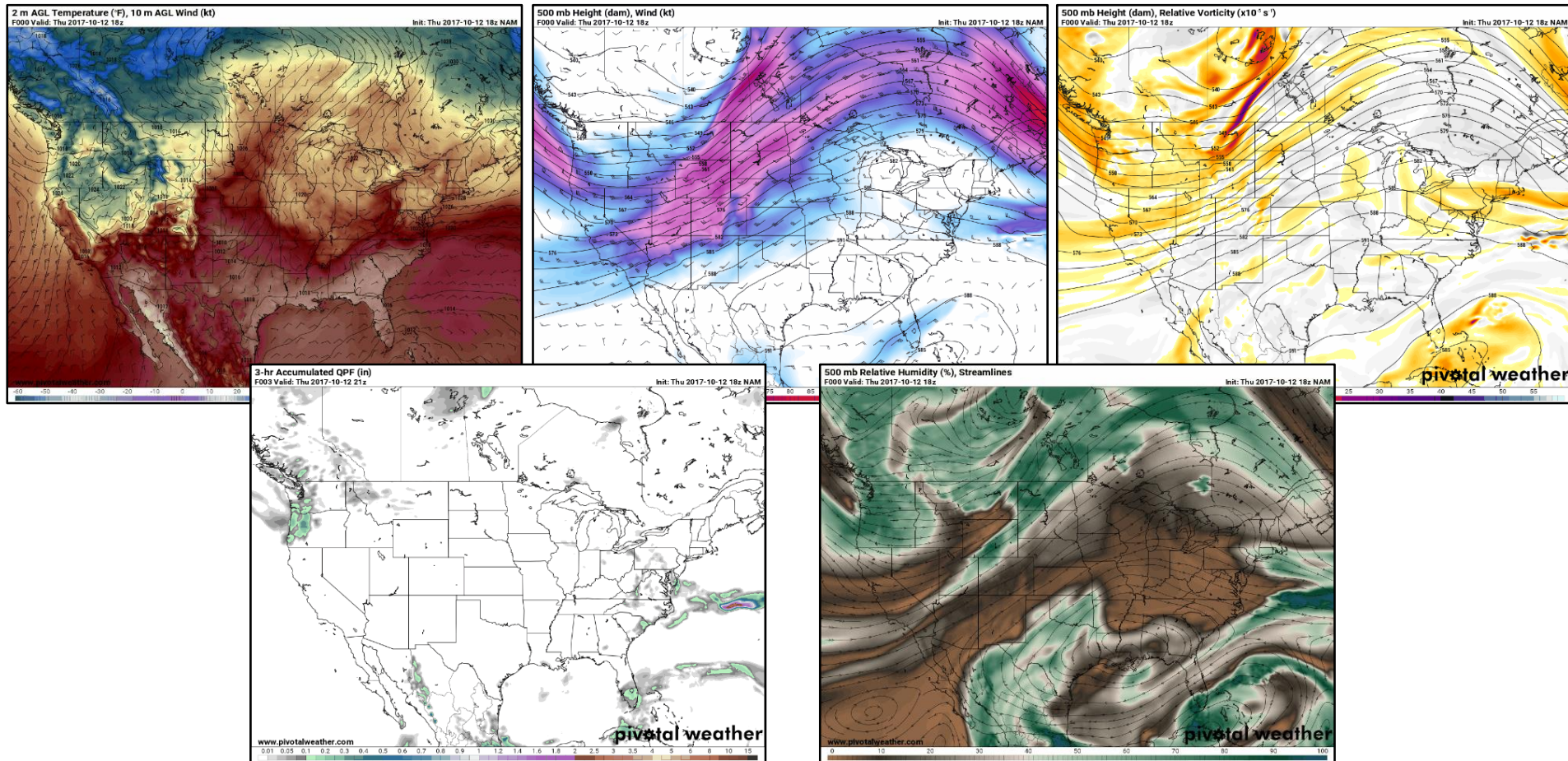
- Persistent area of low pressure removed from the steering flow
- Meander for several days
- Produce unsettled weather

Blocking Patterns

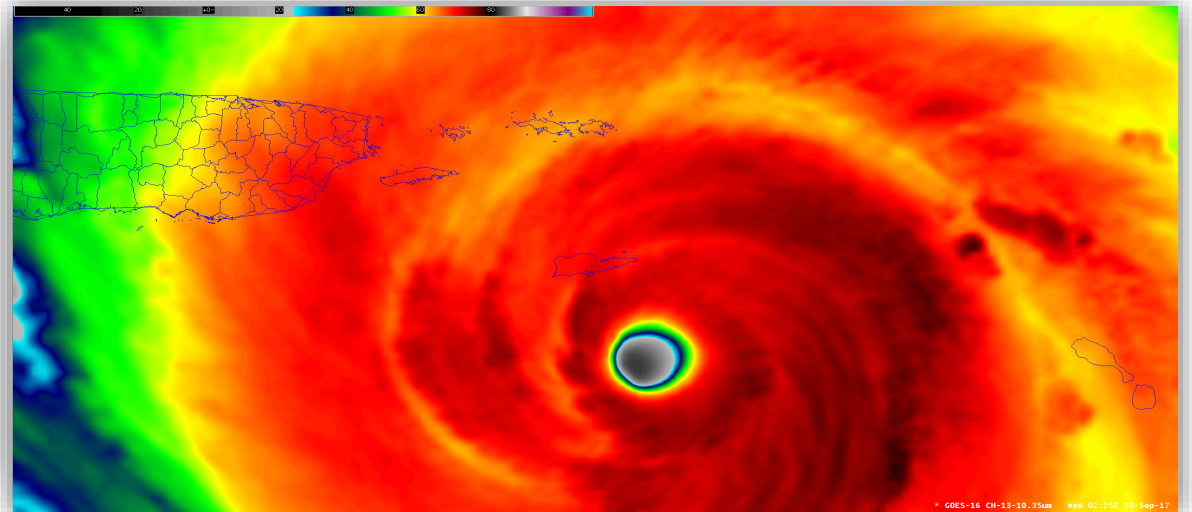
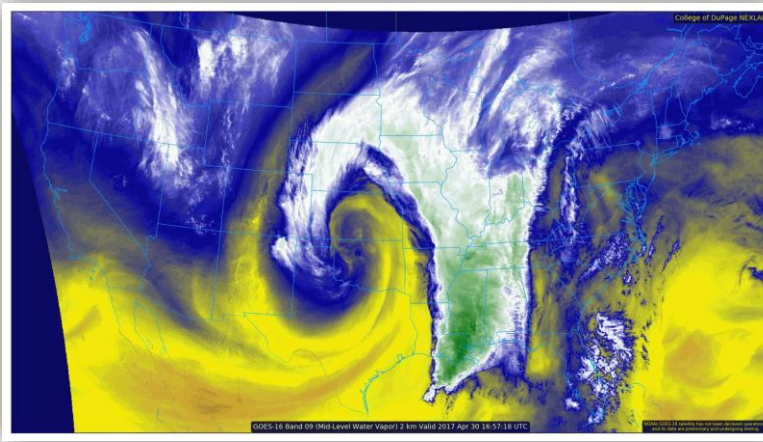
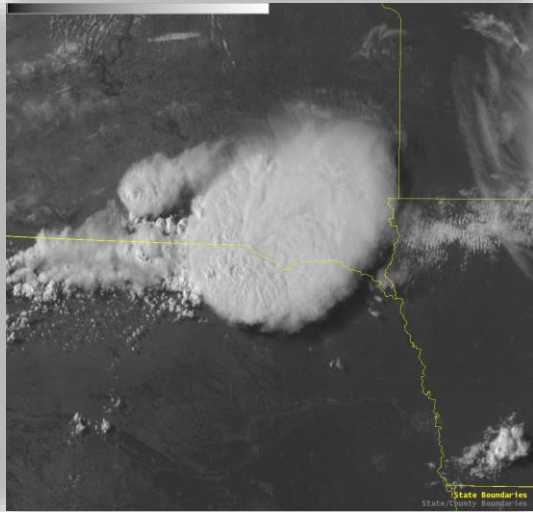


- When weather systems set up in a way that prevents others from moving through
- Weather systems are forced to go around the block
- Result long spans of persistent weather conditions for any given area

A Storm System is Arriving: What is the NWS Up To?

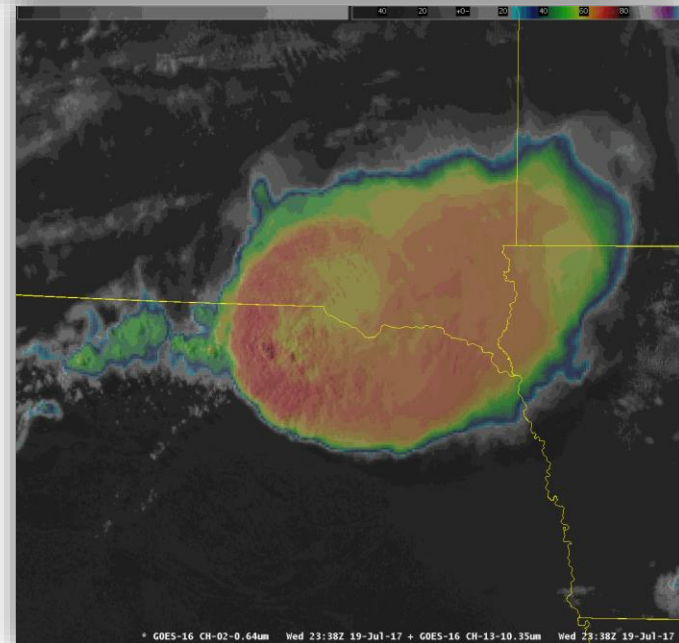
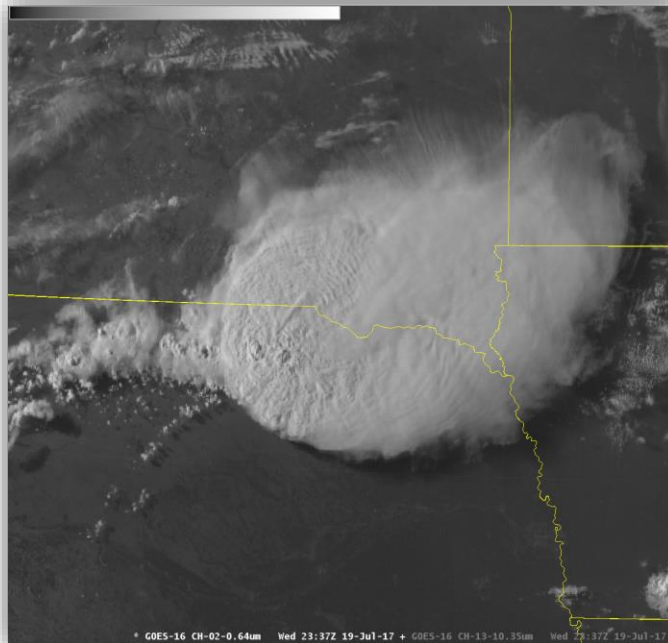
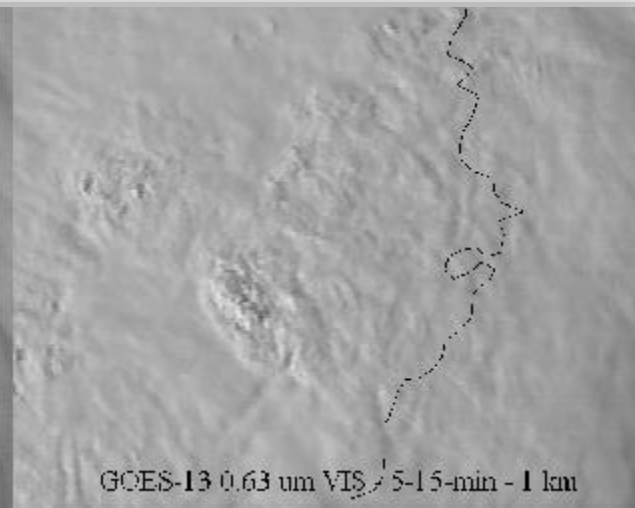
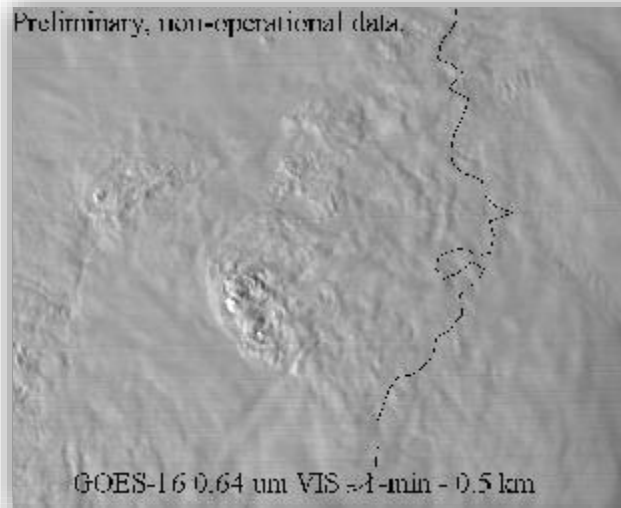


A Storm System is Arriving: What is the NWS Up To?

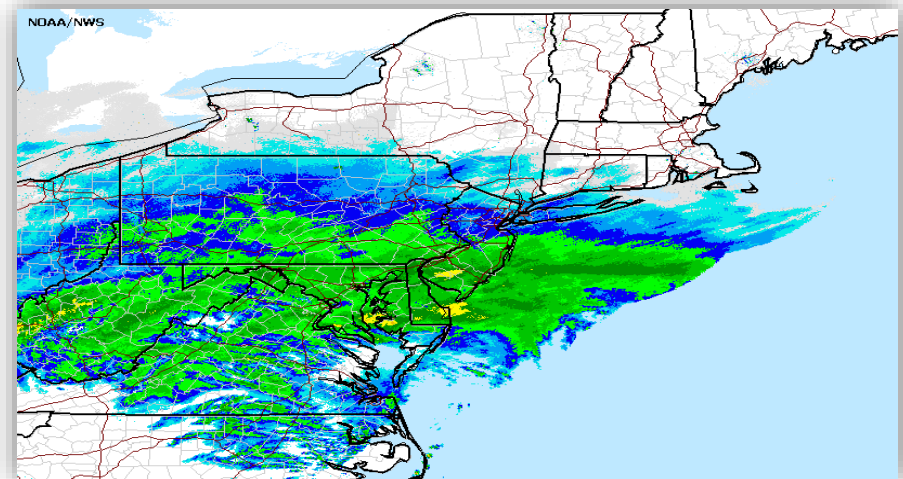
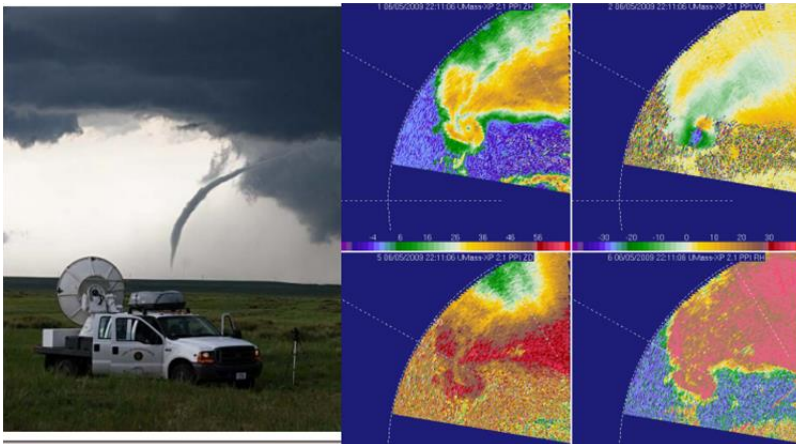
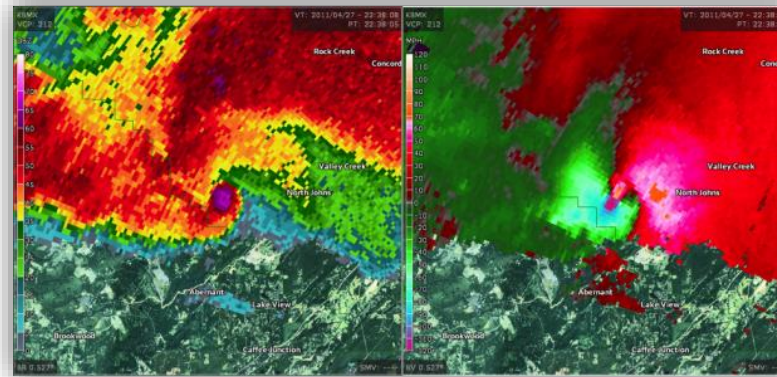
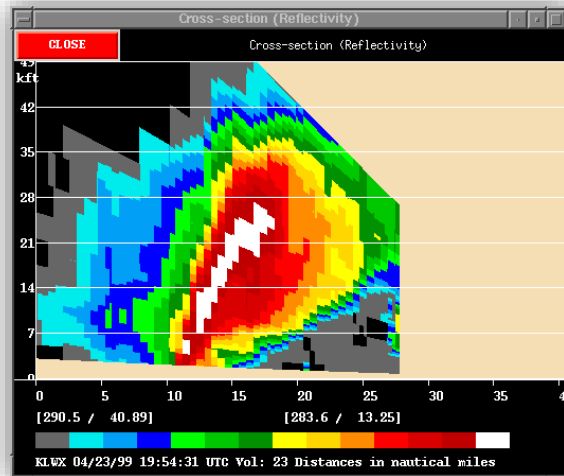


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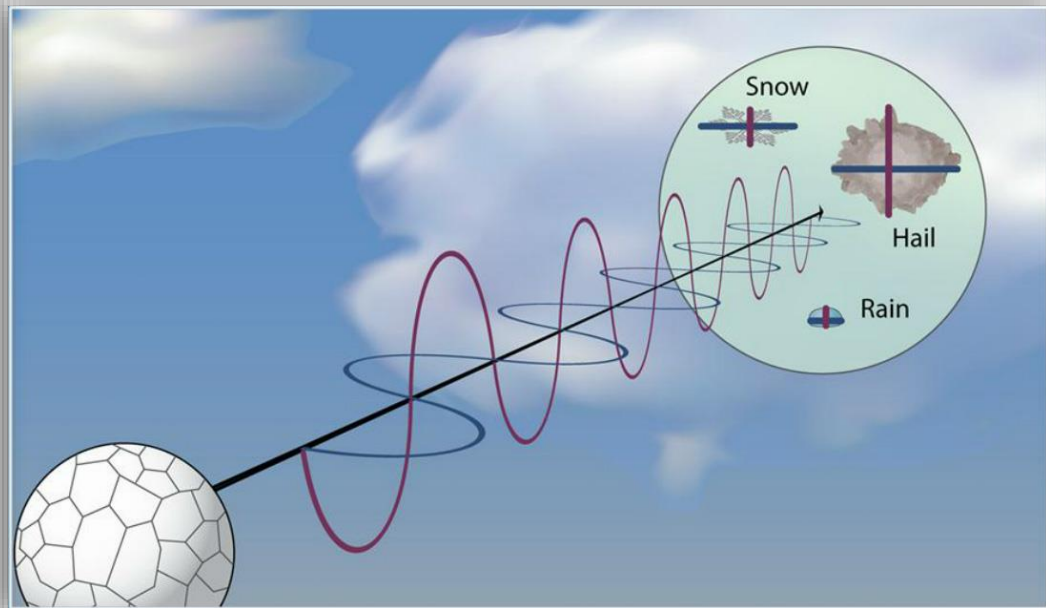
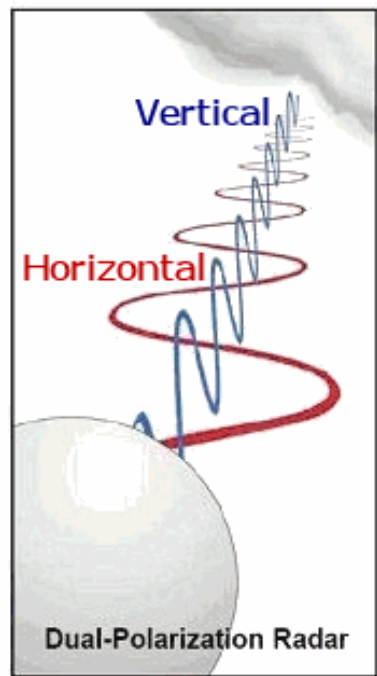
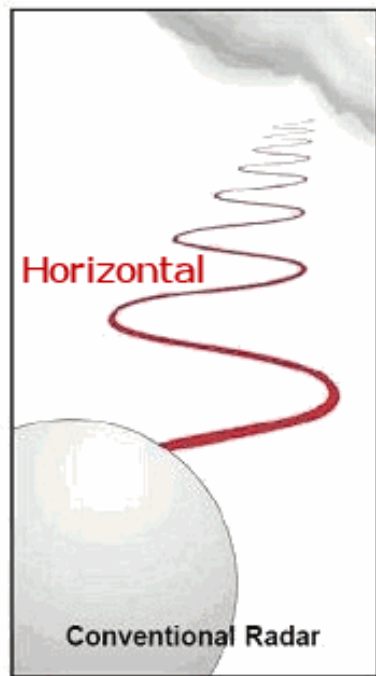
Preliminary, non-operational data.



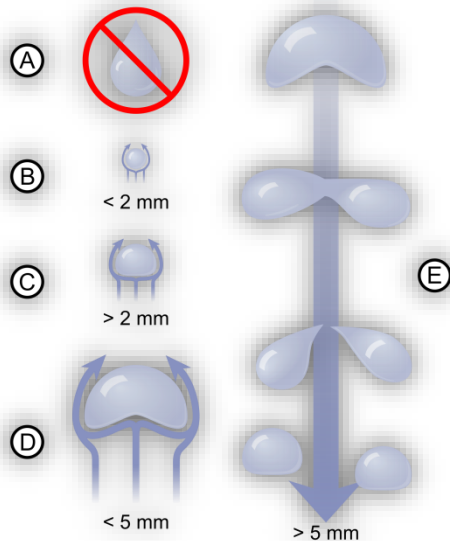
A Storm System is Arriving: What is the NWS Up To?



Dual-polarization Radar



Dual-polarization Radar



Rain



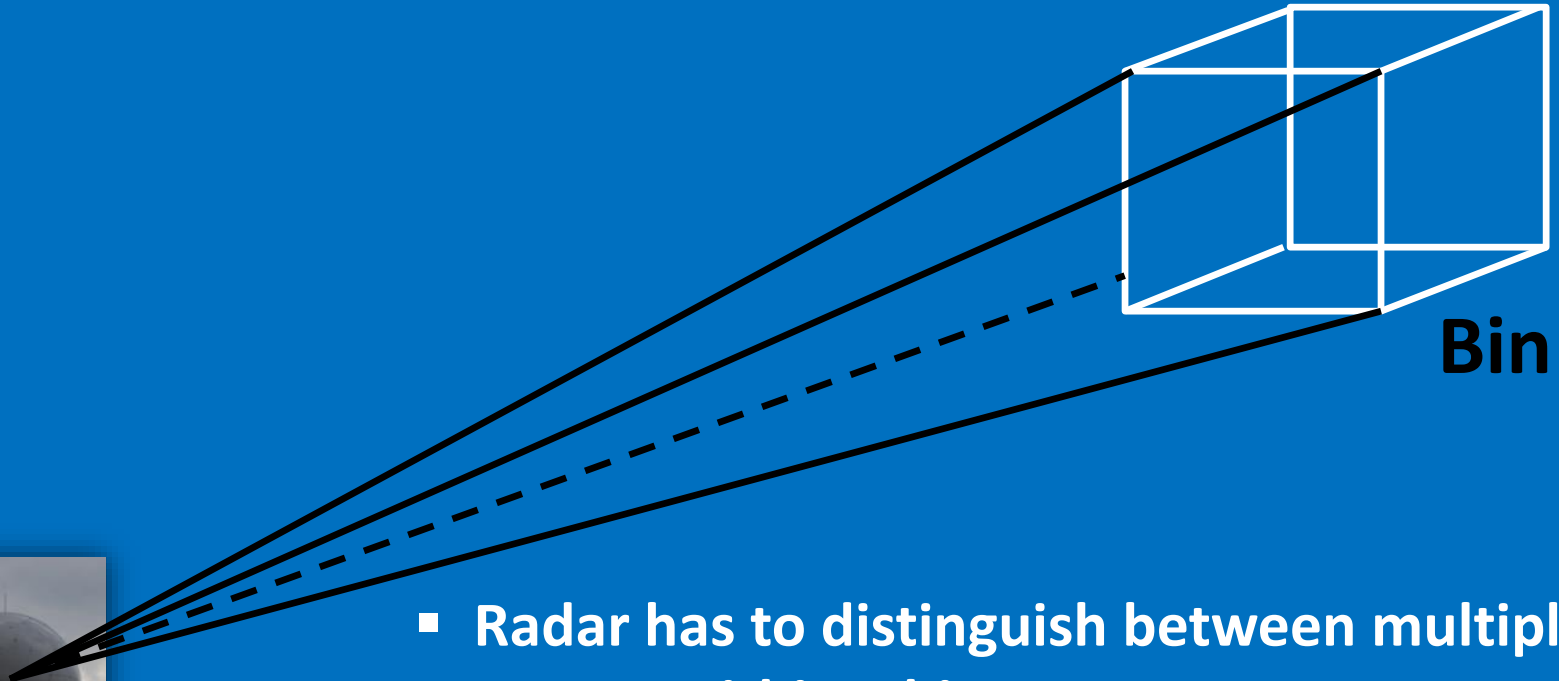
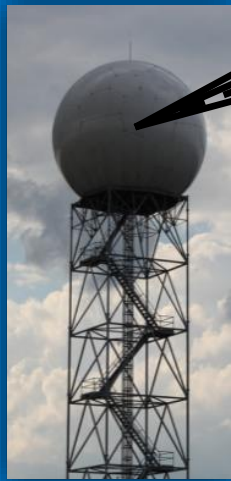
Hail



Tornado Debris

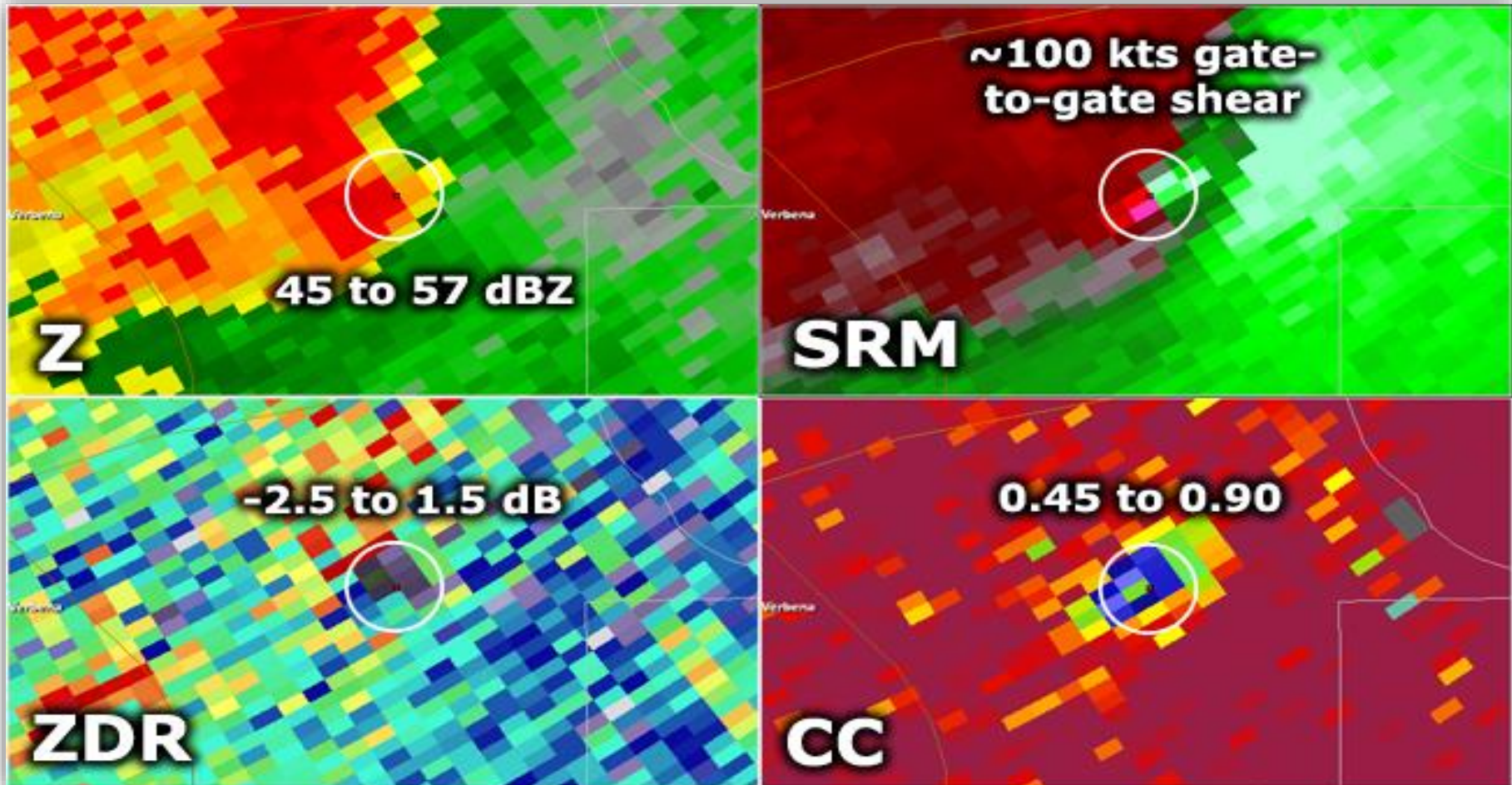
We can determine what the radar is sampling based off horizontal/vertical ratios. Weather-related, or not?

Dual-polarization Radar

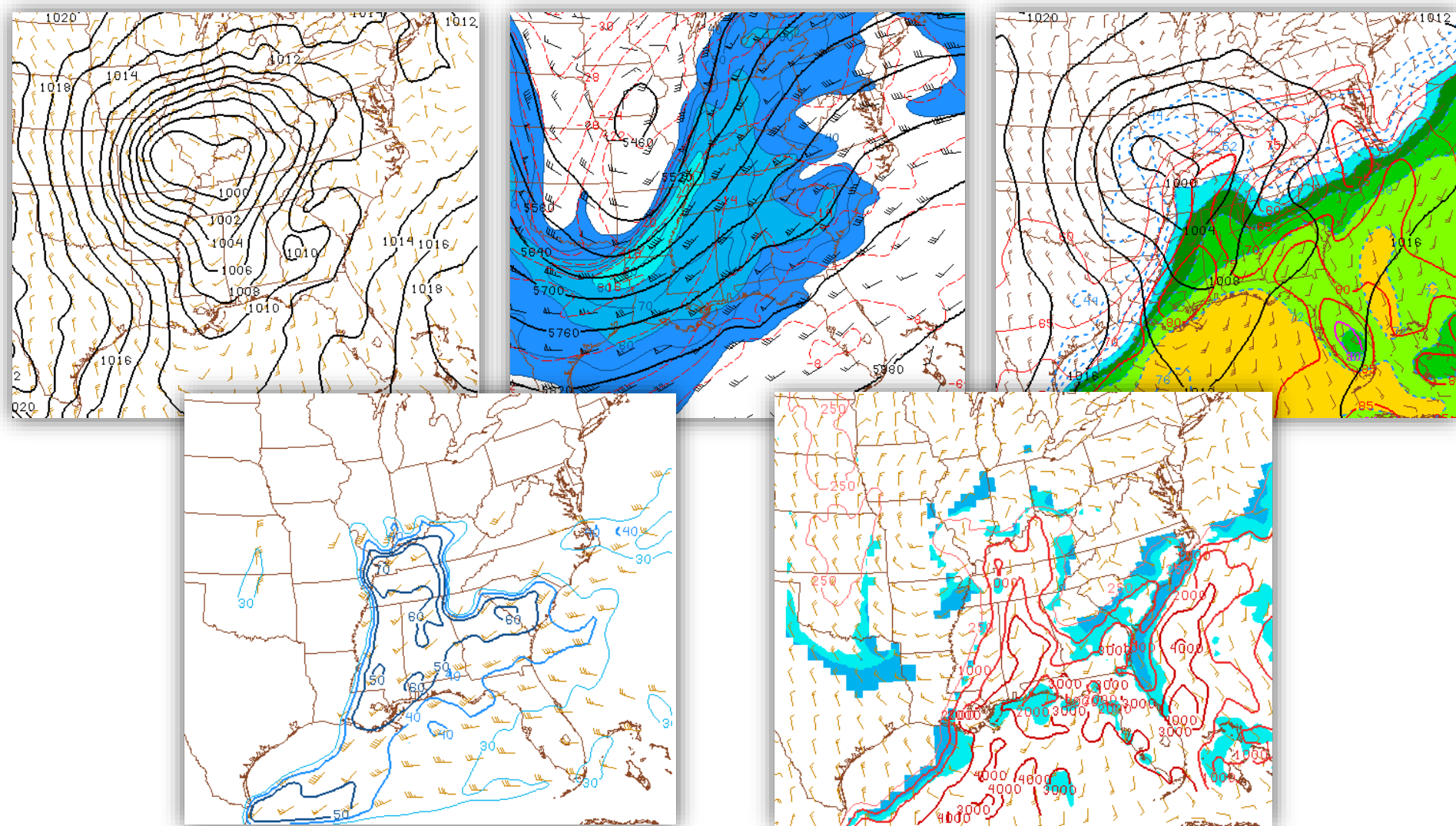


- Radar has to distinguish between multiple targets within a bin
- It calculates the ratios of the targets
- When several kinds of targets are within a bin and their ratios are not correlated, the CC of the bin is lowered

Tornado Debris Signature (TDS)

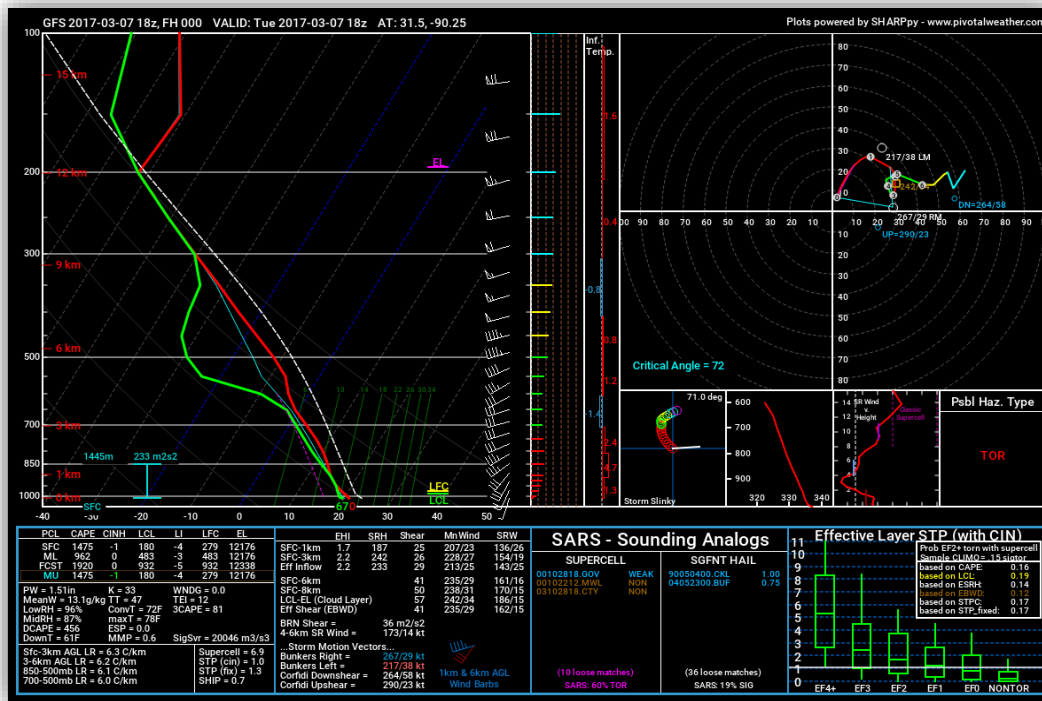


Mesoanalysis



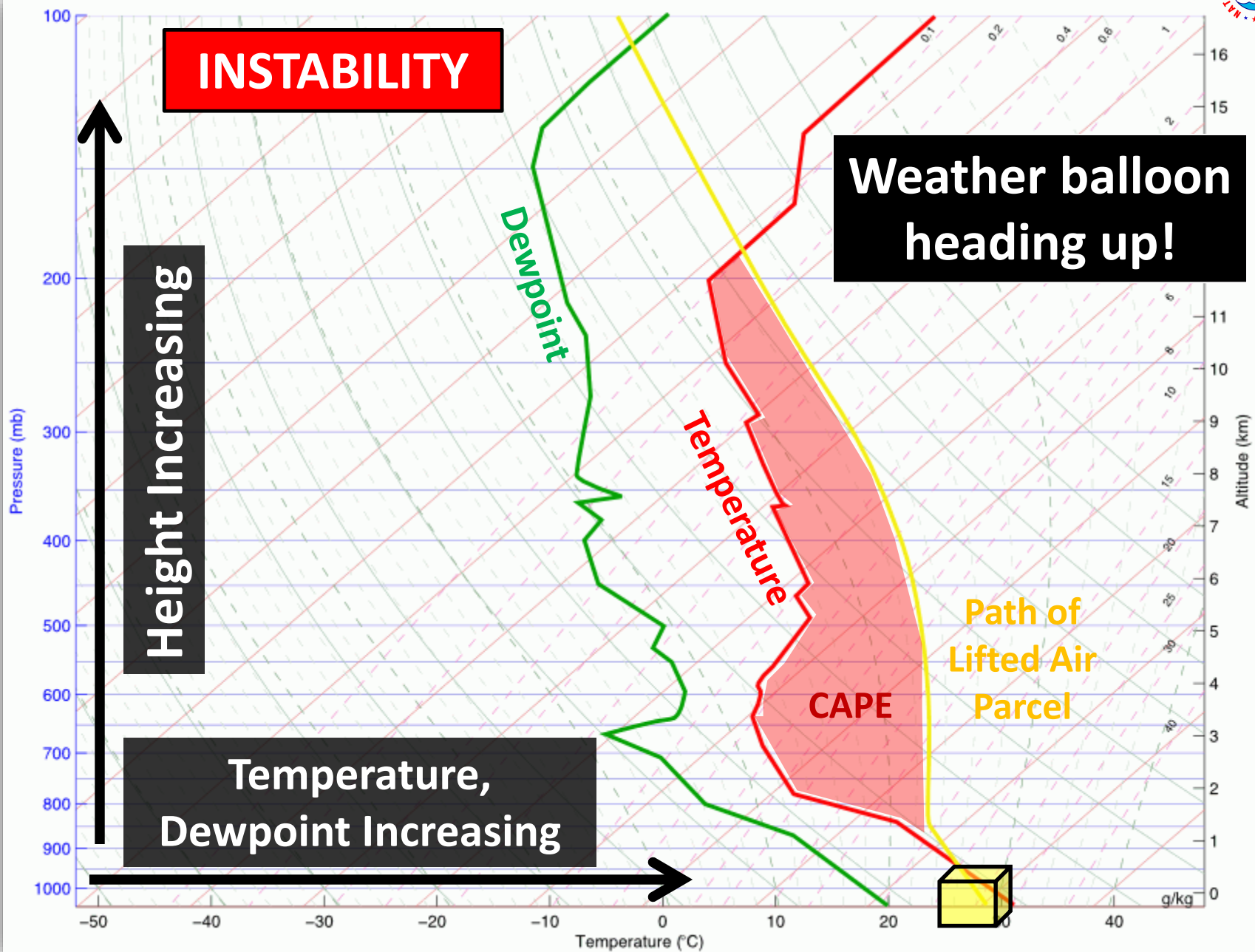
We analyze and assess many severe parameters. Are conditions favorable for severe weather? What kind? To what extent?

What's In a Sounding?

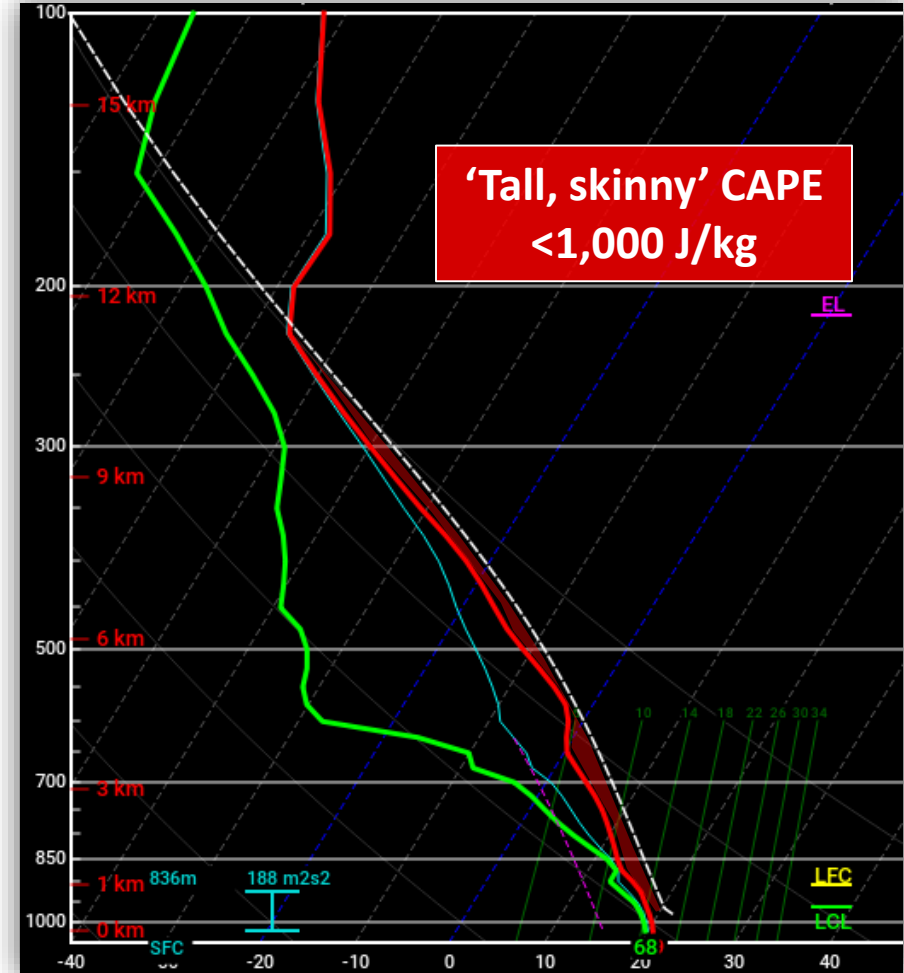
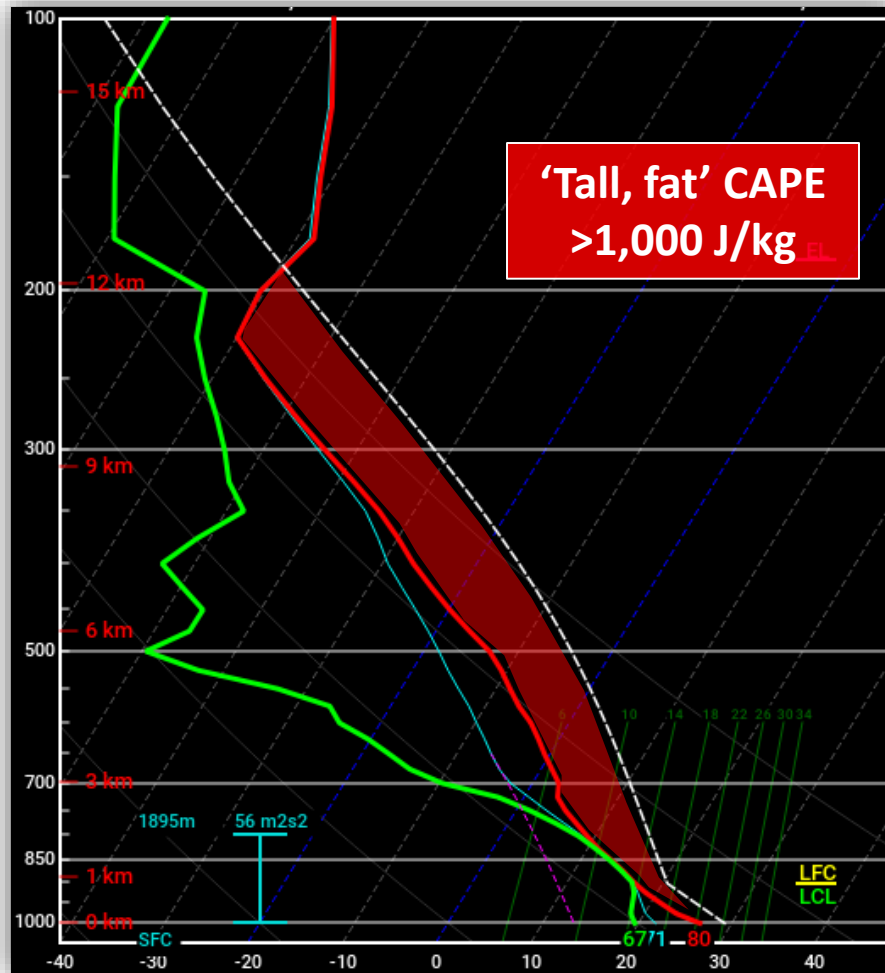


- SRH (storm-relative helicity): measure of potential for rotating updrafts in right-moving storms
- 0-1km; 0-3km shear magnitude
- Bulk shear: Measure of deep-layer shear
- Wind vector from surface-850mb-500mb

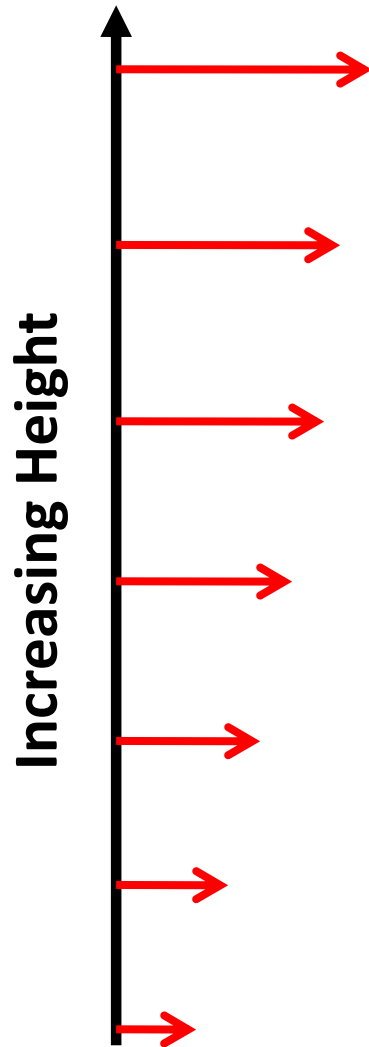
- LCL (lifted condensation level): level at which a lifted parcel becomes saturated
- LFC (level of free convection): Level at which a parcel freely accelerates upward to equilibrium level
- EL (equilibrium level): Level at which a lifted parcel is no longer buoyant
- Lapse rates: rate of temperature change with height
- CAPE (convective available potential energy): measure of instability
- DCAPE: measure of potential strength of rain-cooled downdrafts
- CIN (convective inhibition): measure of stability
- LI (lifted index): temperature difference between 500mb temp and lifted parcel temp at 500mb



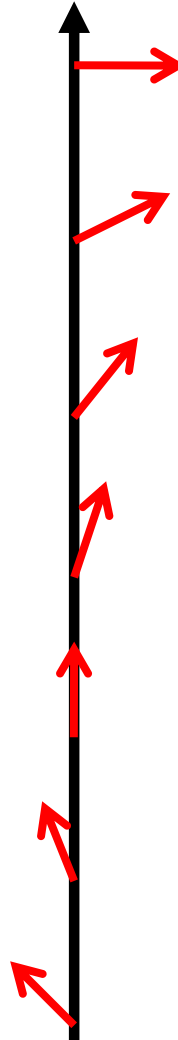
Weak vs. Strong CAPE (Convective Available Potential Energy)



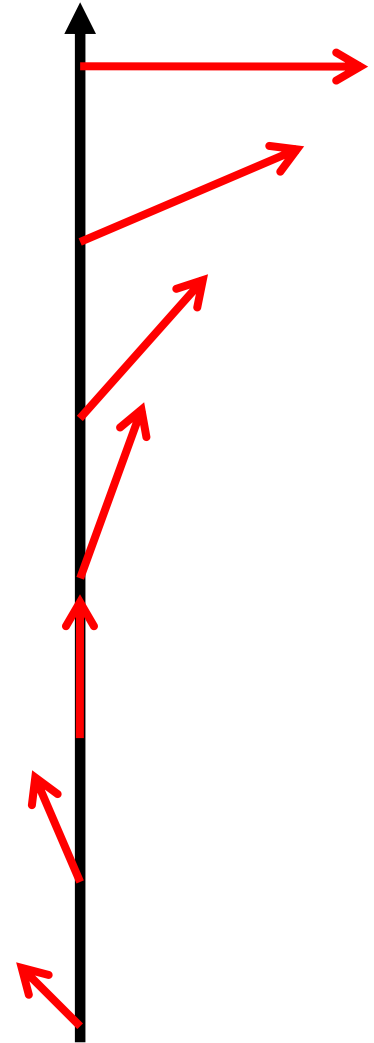
Wind Shear



Change in wind speed
with height

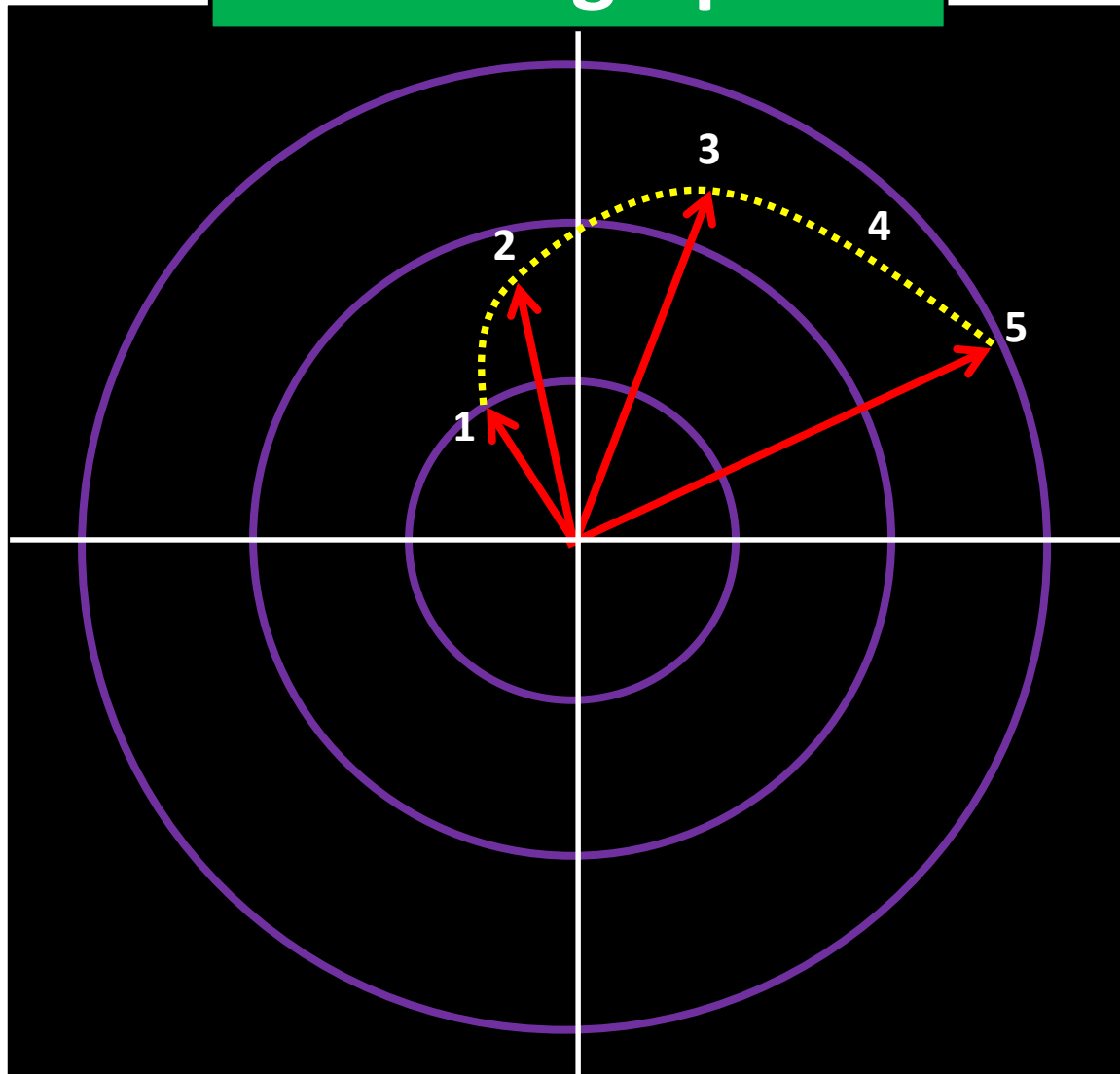


Change in wind direction with
height

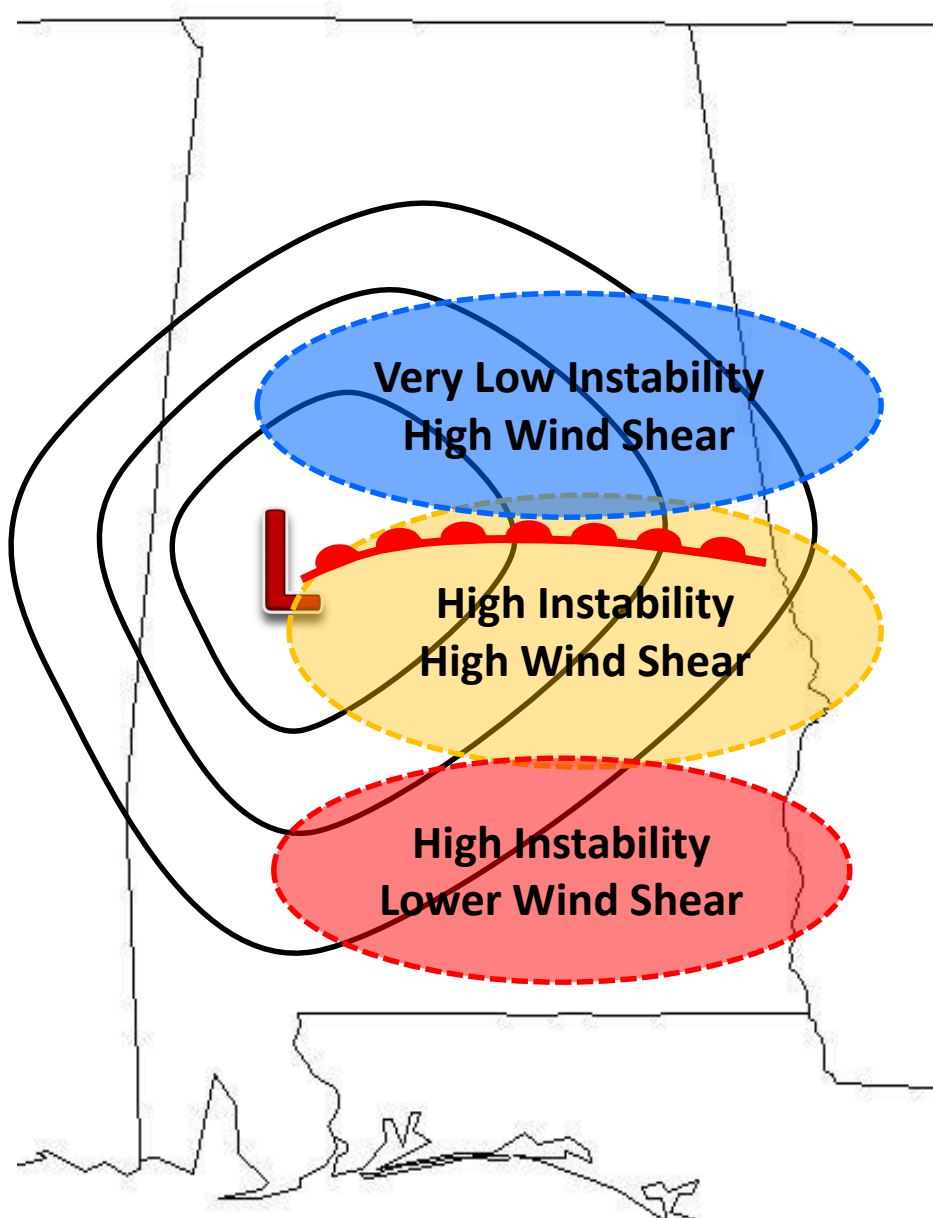


Change in wind speed and direction
with height

Hodograph



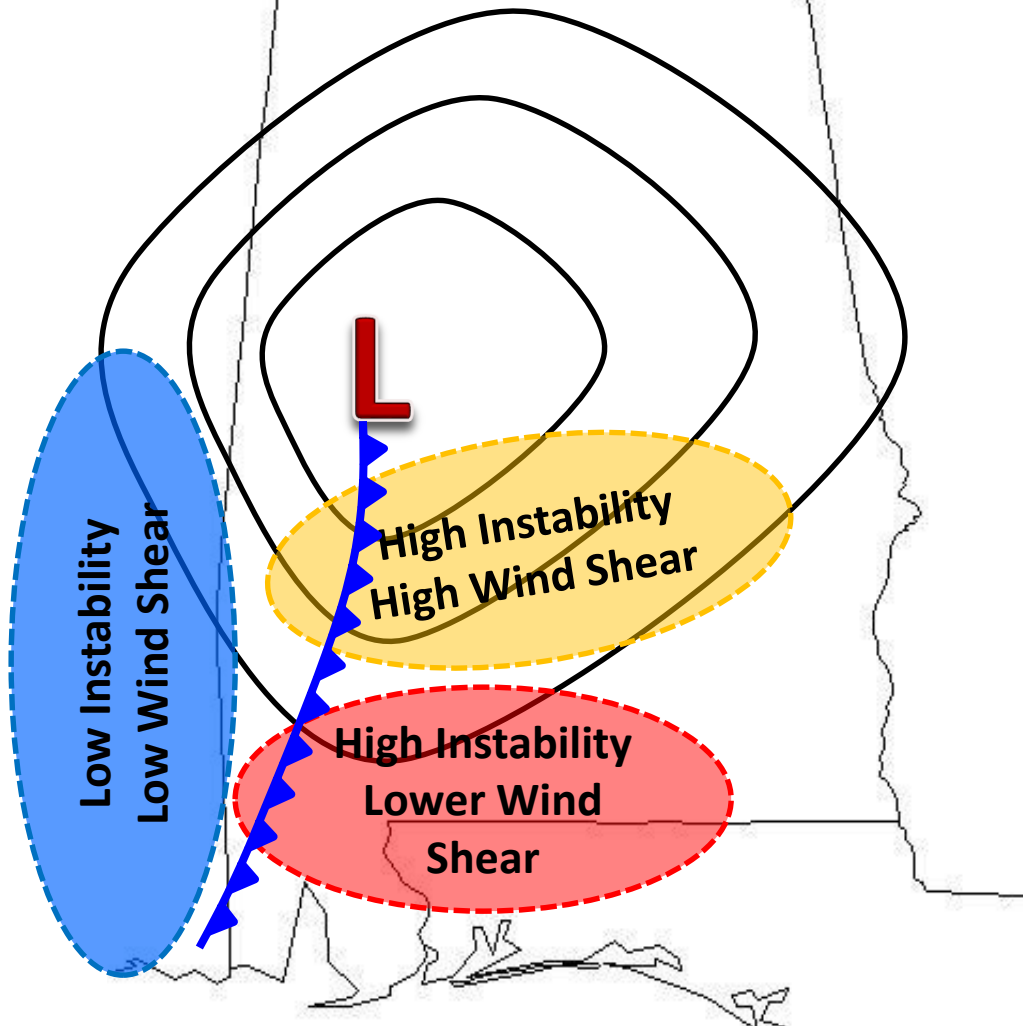
- Wind shear is typically calculated in terms of speed and direction. The change in these is known as helicity or storm-relative helicity
- Helicity is measured at several heights. Helps determine what type of storm is likely to form/severe hazards



Warm Front

- Typically have a distinct wind shift from the south to the east across the front
- Increasing instability south of the warm front, lower north
- Wind shear highest near and north of the warm front

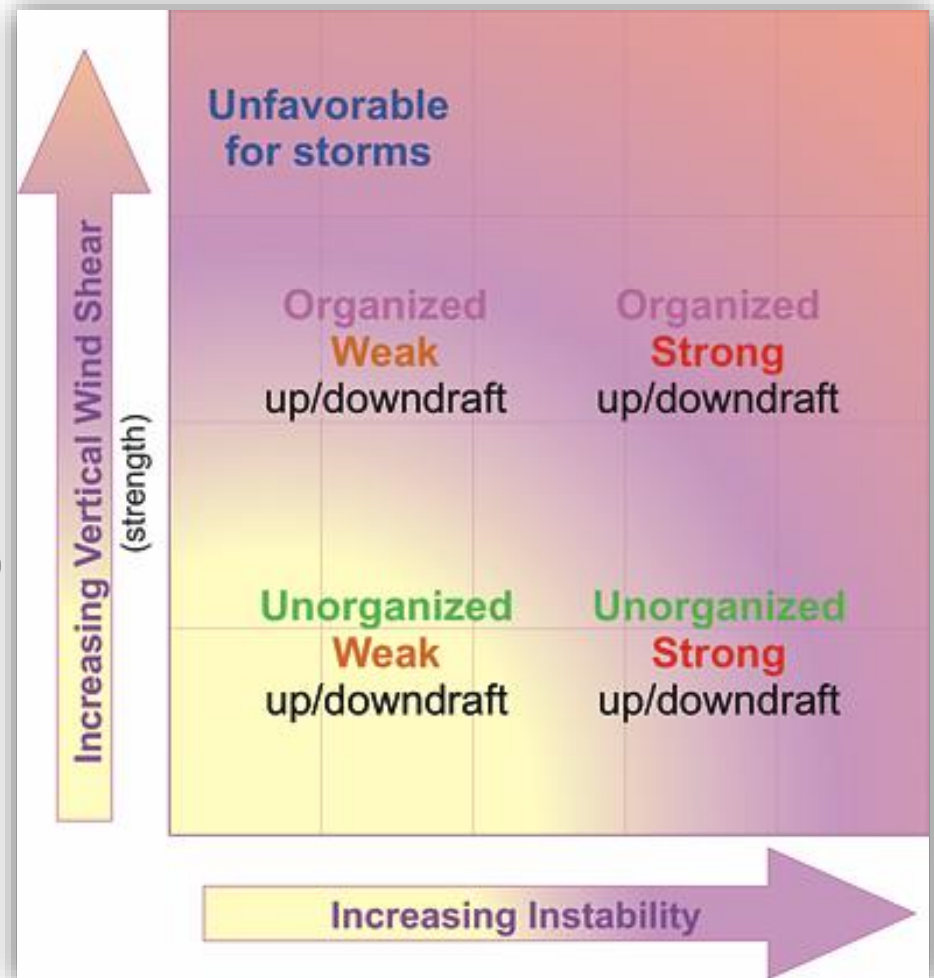
Cold Front



- Typically have an abrupt wind shift from the south to northwest across the front
- Unstable ahead of front, increasingly stable behind
- Wind shear highest ahead of front, lowest behind

Recall: Thunderstorm Ingredients

- Lift
 - Cold front
 - Warm front
 - Gust front, outflow boundary
 - Terrain (upslope flow)
 - Surface heating
- Moisture
- Instability



*Wind Shear helps with thunderstorm organization/longevity and severity

Severe Thunderstorm Parameters

Storm Type? Severity?

Vertical Wind Shear & SRH

- 0-6 km bulk shear > 40 kts – supercells
- 0-6 km bulk shear 20-35 kts – organized multicells
- 0-6 km bulk shear < 10-20 kts – disorganized multicells
- 0-8 km bulk shear > 52 kts – long-lived supercells
- 0-3 km bulk shear > 30-40 kts – bowing thunderstorms

SRH

- 0-3 km SRH > $150 \text{ m}^2 \text{ s}^{-2}$ = updraft rotation becomes more likely
- 0-3 km SRH > 300-400 $\text{m}^2 \text{ s}^{-2}$ = rotating updrafts and supercell development likely

BOTH

- 0-6 km shear < 35 kts with 0-3 km SRH > $150 \text{ m}^2 \text{ s}^{-2}$ – brief rotation but not persistent
- 0-6 km shear < 35 kts – any storm that acquires rotation will not persist for very long
- 0-6 km shear > 40 kts with 0-3 km SRH < $150 \text{ m}^2 \text{ s}^{-2}$ – a supercell can still develop
- 0-6 km shear > 40 kts with 0-3 km SRH > $150 \text{ m}^2 \text{ s}^{-2}$ – updraft rotation may be strong
- When 0-6 km shear is 30-40 kts (i.e., marginal), but the atmosphere is very unstable
- CAPE > 2500 J kg^{-1} , supercells can still form. This is especially true along low-level boundaries.

Large Hail

- -10 to -30° C layer is the hail growth zone; look for a large CAPE within -10 to -30° C layer
- Rotating updraft – the longer hail resides within hail growth zone, the greater the potential for large hail

Supercells & Hail

- Large boundary layer moisture
- 700-500 mb lapse rates > 7.0 C km^{-1}
- Moderate to large CAPE, including "fat" CAPE for rapid acceleration
- 0-6 km shear > 40-50 kts (includes speed and directional)
- 0-3 km SRH > $150\text{-}200 \text{ m}^2 \text{ s}^{-2}$

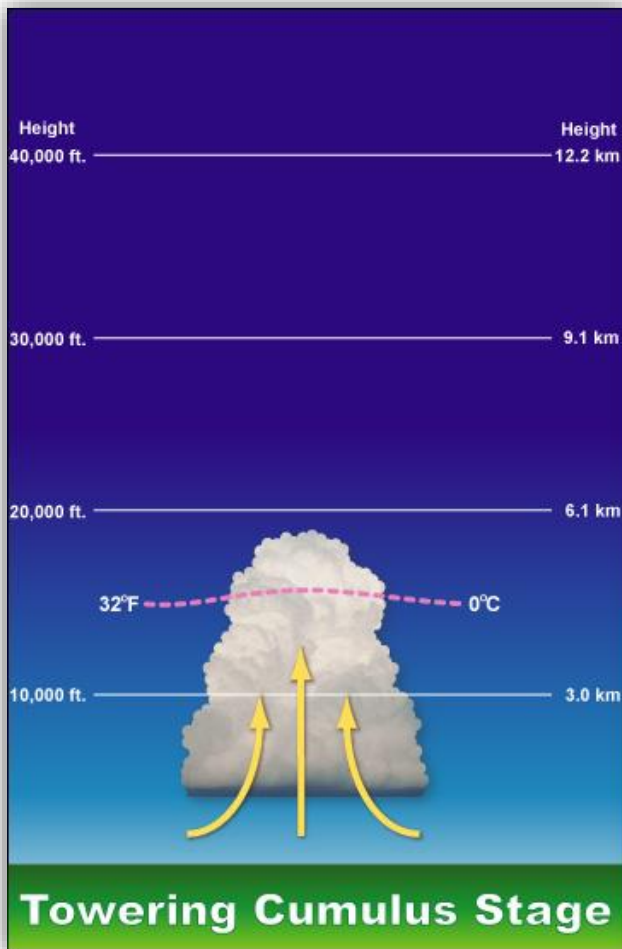
Hodograph:

- The 0-1 km hodograph spike is relatively straight (no curvature). Above the spike, the hodograph then displays stronger turning and curvature.
- 0-1 km bulk shear > 20 kts
- 0-1 km SRH > $150\text{-}300 \text{ m}^2 \text{ s}^{-2}$
- Boundary layer RH > 65%
- LCL heights $\leq 1000 \text{ m}$ (3000 ft)
- Most of the 0-3 km SRH is concentrated in 0-1 km layer
- Low LCL heights (large boundary layer RH) favor warm RFDs and tornadogenesis
- High LCL heights (low boundary layer RH) favor cold RFDs and tornadogenesis-failure

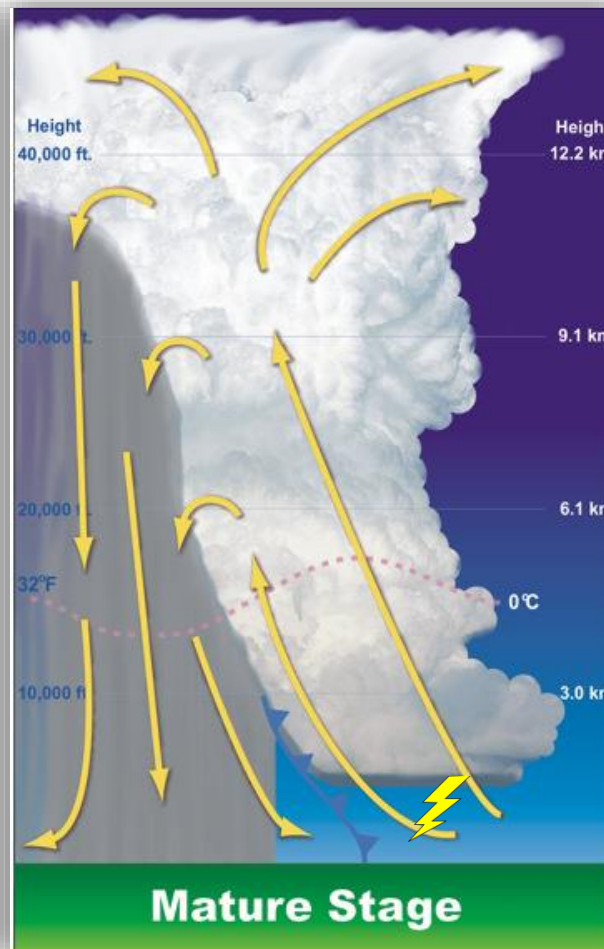
Derechoes

- Prolonged bow echo/damaging wind events; favored in environments with high to extreme instability; fast low to mid-level unidirectional flow
- 0-3 km bulk shear > 30 kts; 0-6 km bulk shear > 40 kts

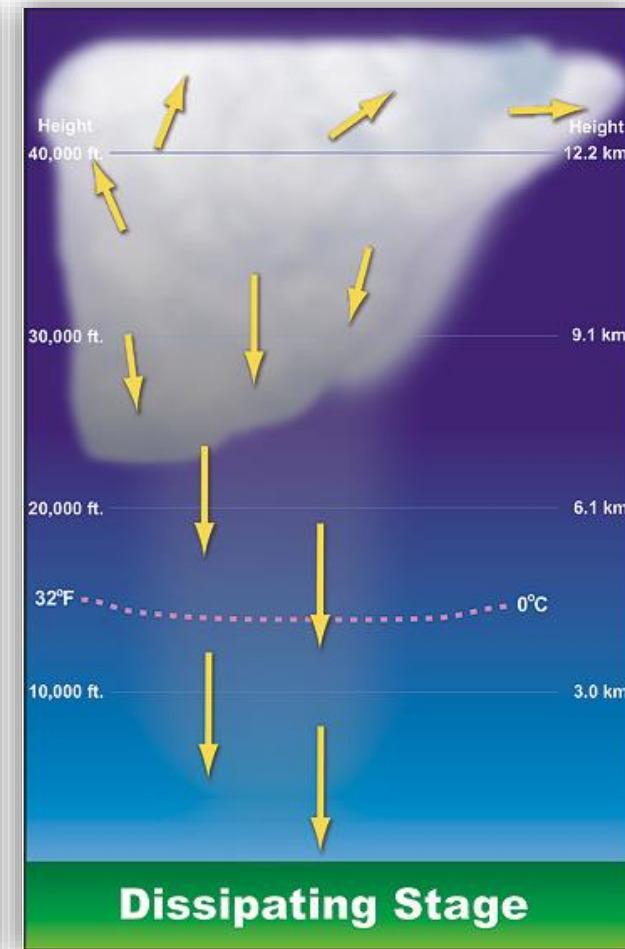
Thunderstorm Stages



- Updraft dominates
- Cumulus cloud grows vertically
- Up to ~20,000 feet tall

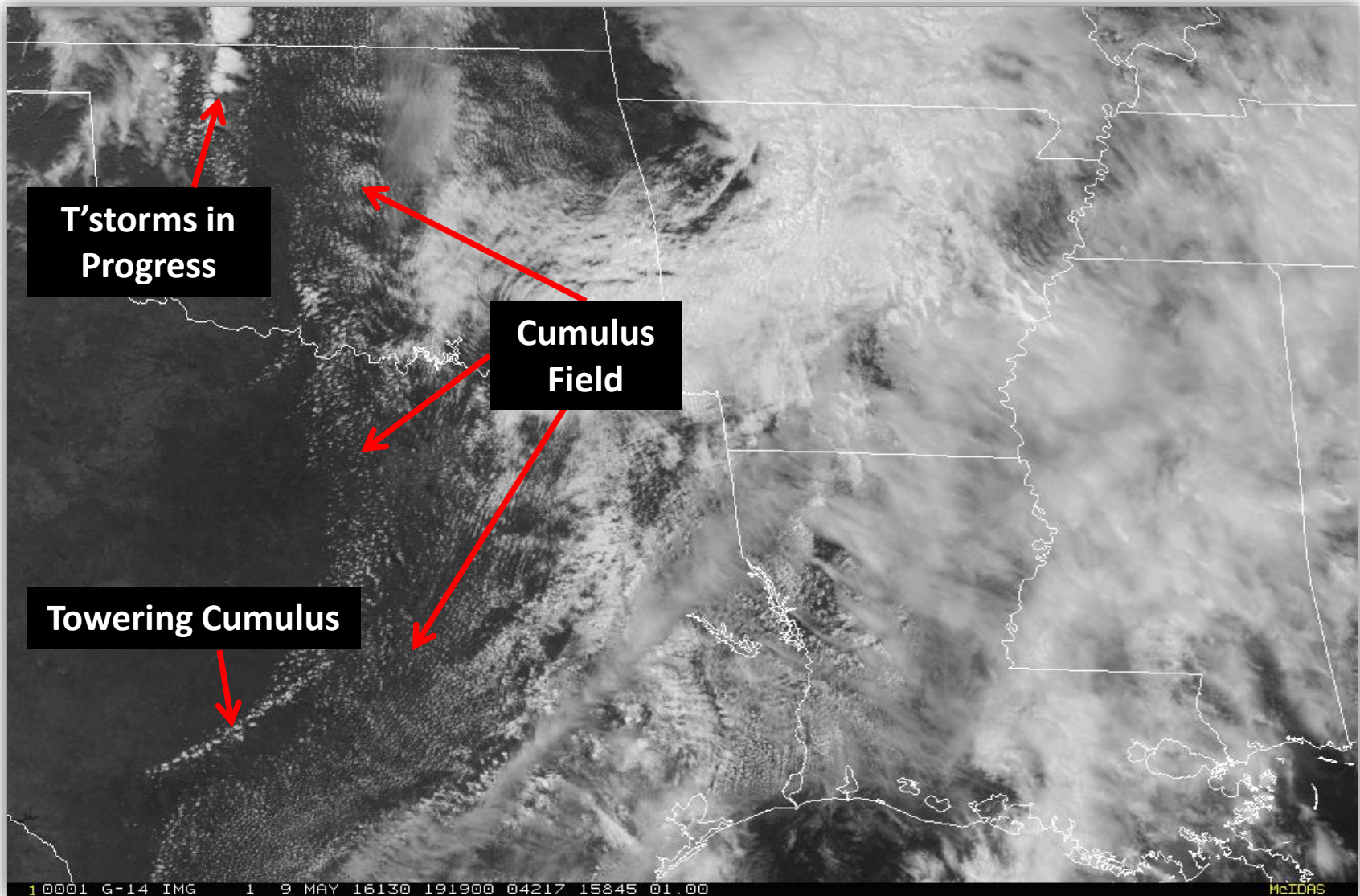


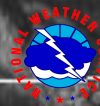
- ~40,000 to 60,000 feet tall
- Strong updraft and downdraft coexist
- Large hail, damaging winds, tornado(es), and flooding rain may occur



- Downdraft cuts off updraft
- Rain, gusty winds, and last lightning strike
- Remnant anvil cloud aloft

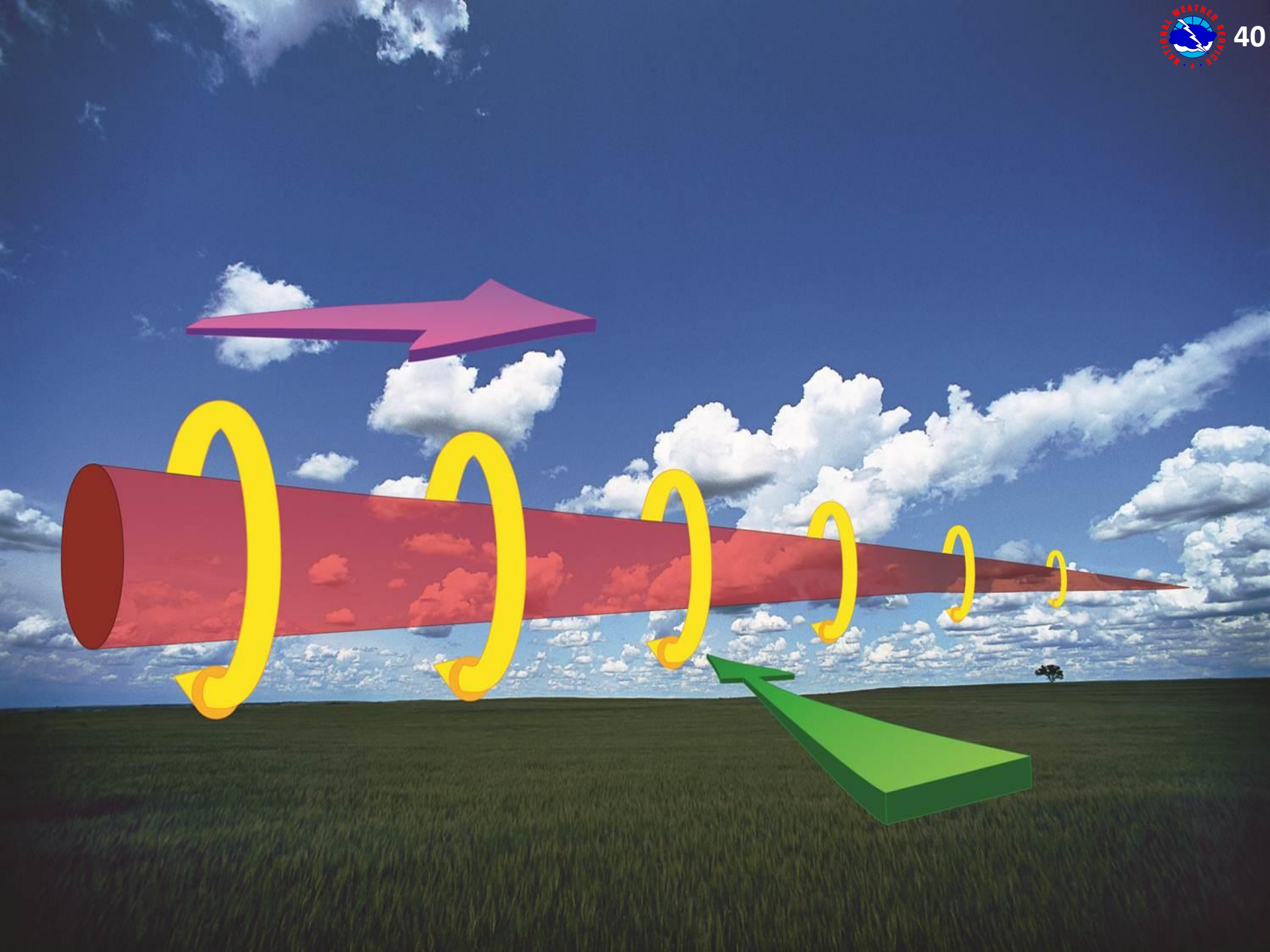
Stages of Activity

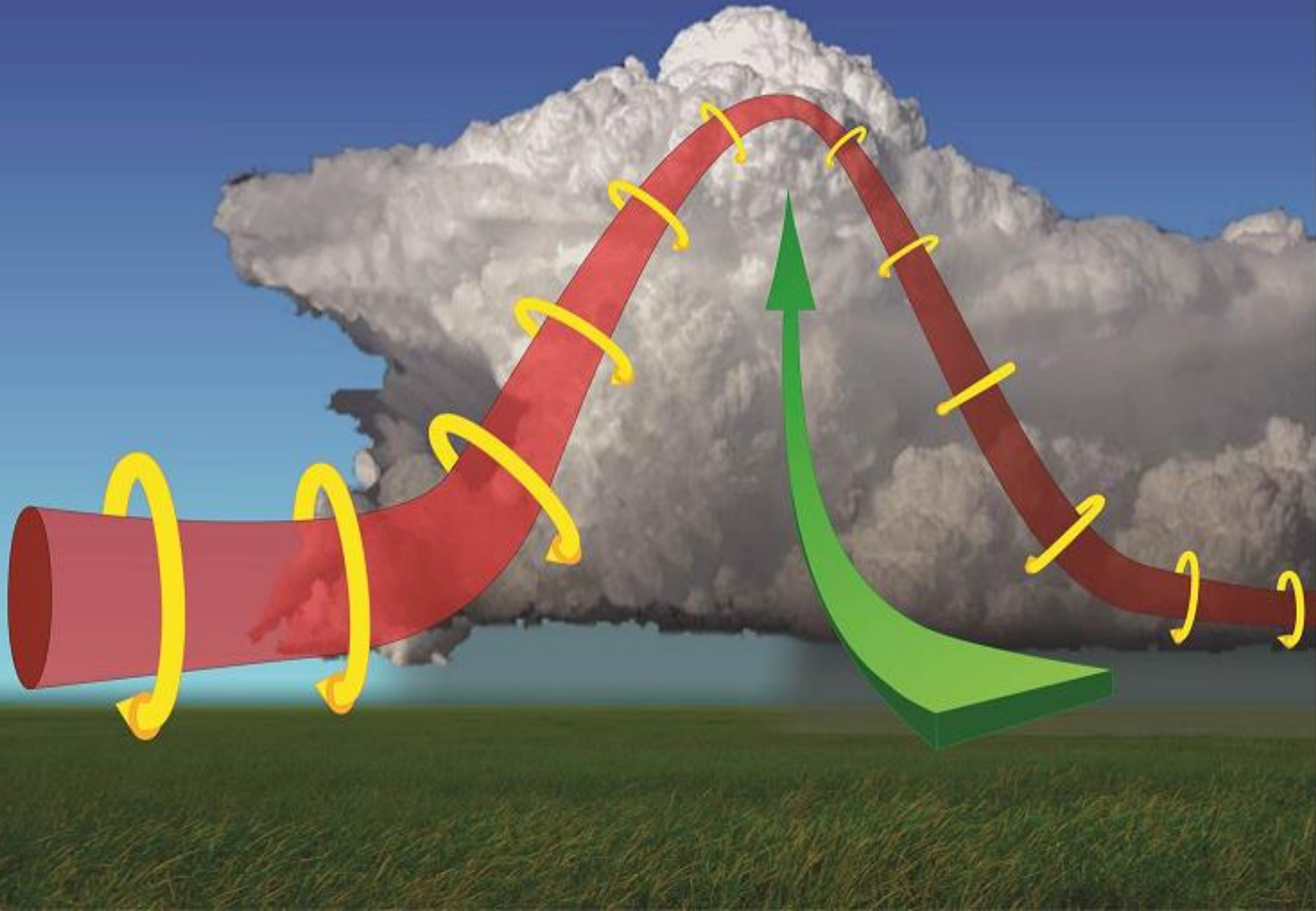




GOES-16 One-Minute Imagery!!









Funnel Cloud

- A rotating, funnel-shaped cloud extending downward from a thunderstorm base
- Most often laminar or smooth in appearance
- Usually located near the updraft
- Attached to cloud base
- Funnel clouds do not reach the ground!

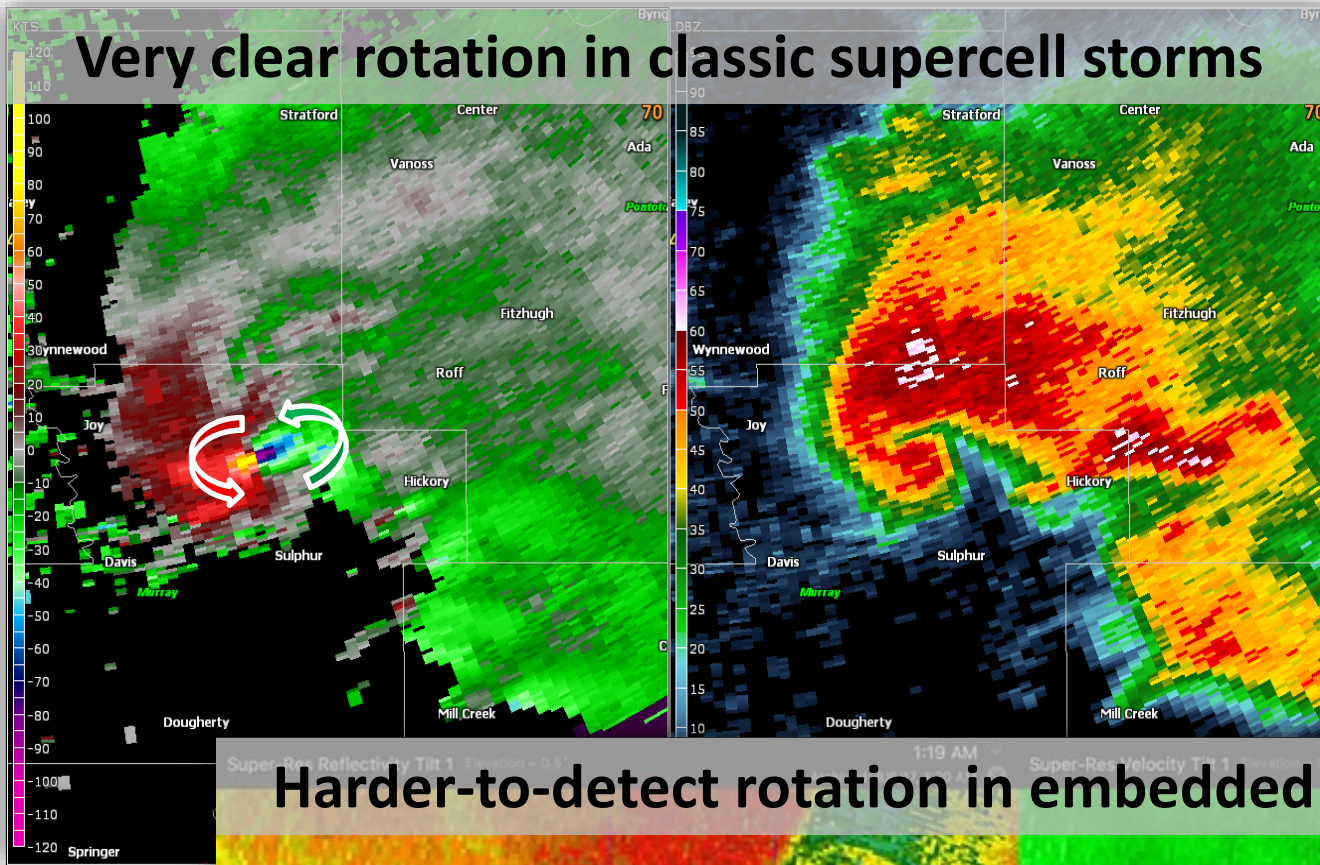


Then (maybe), Tornado!

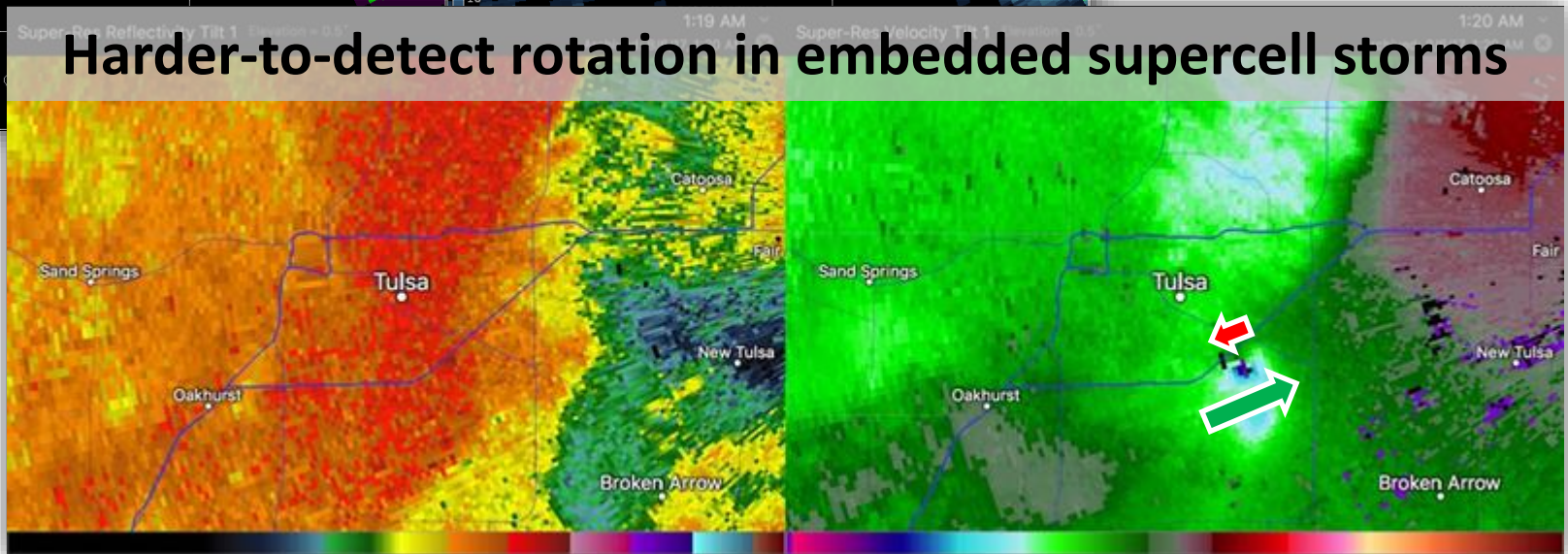
- A violently-rotating column of air extending from cloud base to the ground
- The condensation cloud (part of the tornado, funnel you can see) may not extend all the way to the ground, but any debris kicked up along the ground indicates contact!



Very clear rotation in classic supercell storms



Harder-to-detect rotation in embedded supercell storms



Scud Clouds: Tornado Look-Alikes

- Cloud fragments that are unattached, or rising into the storm's base
- They do not rotate; thus, not a funnel cloud, not a tornado – harmless!

Depending on the situation, rising scud clouds can organize to form a wall cloud at the storm's base. In this case, watch for further development and rotation.





Halftime!
10-minute Break

* GOES-16 CH-13-10.35um Wed 02:25Z 20-Sep-17

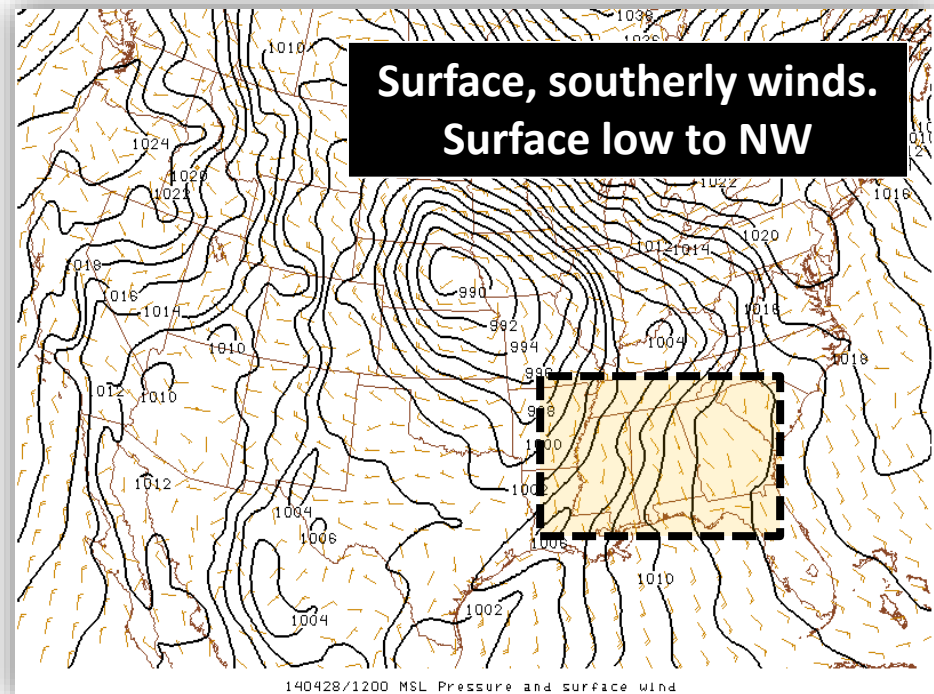
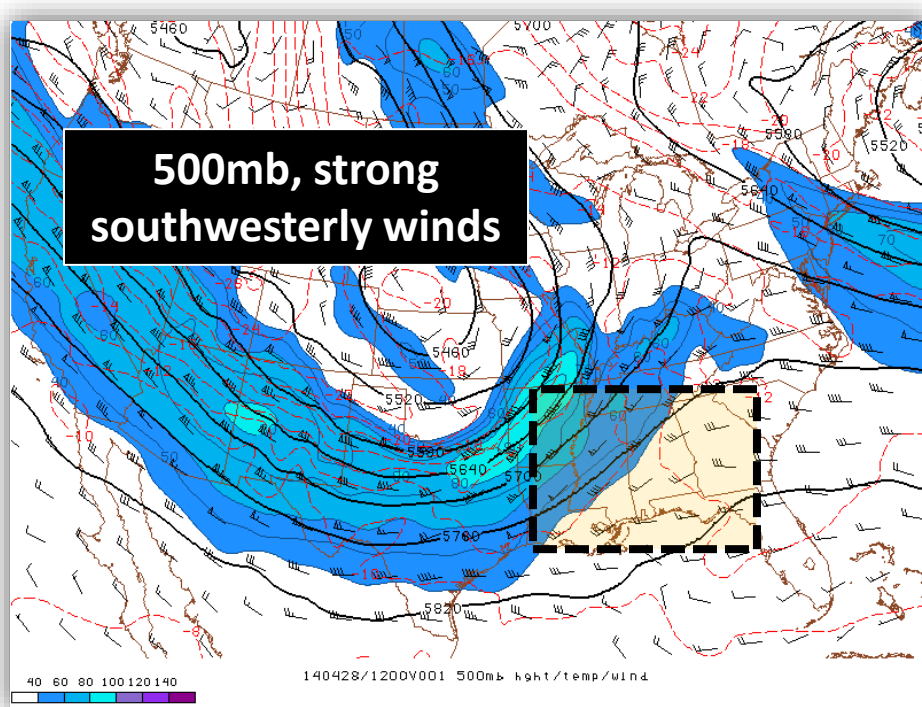




Let's Demo an Event!
April 28-29, 2014

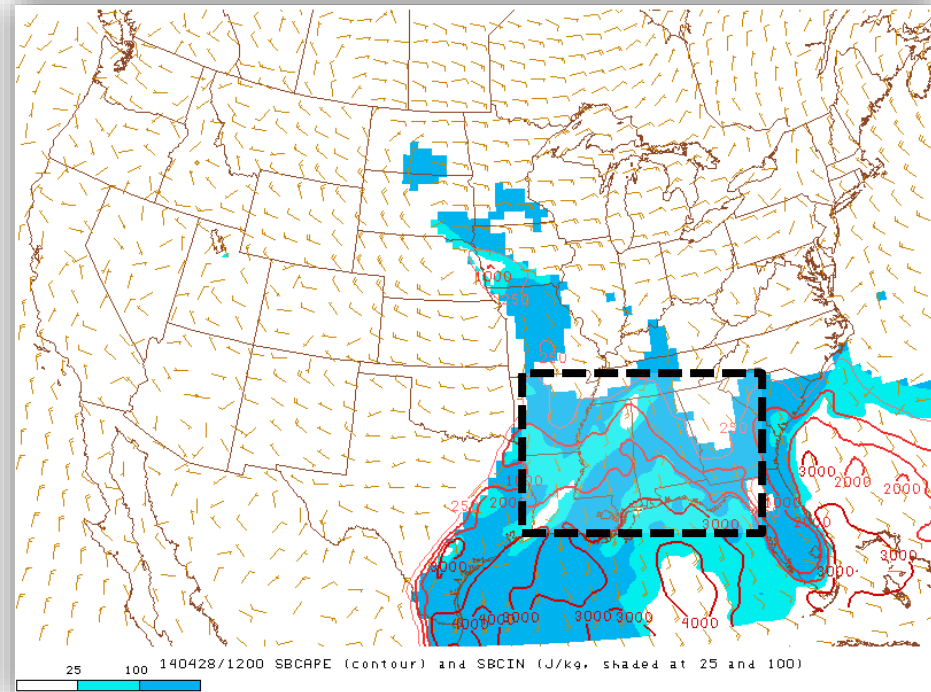
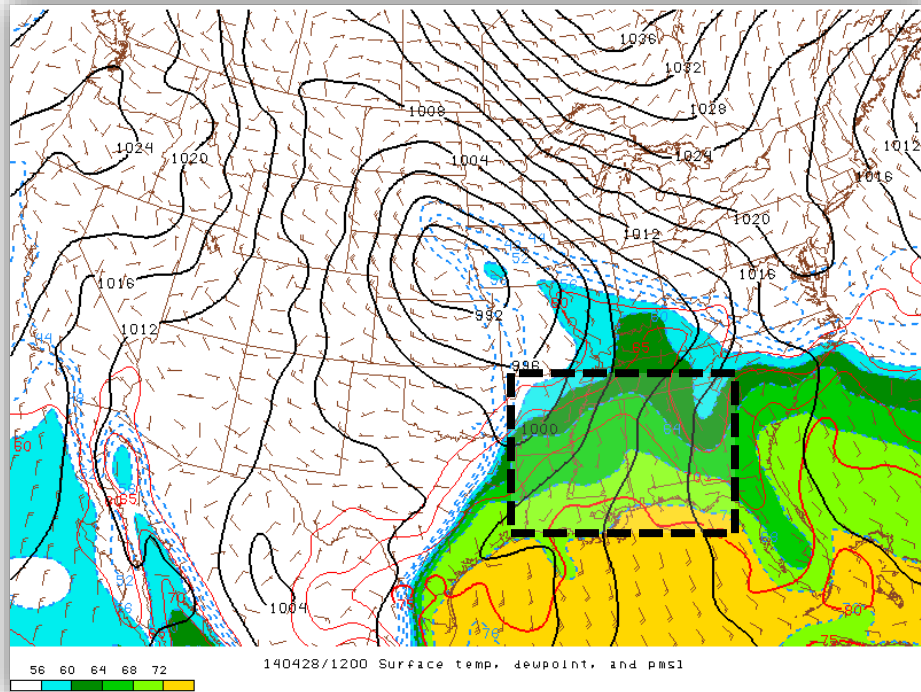


Overall Setup: 12Z/6AM April 28-29, 2014



Speed and directional shear are present: southerly surface winds veering to the southwest aloft while increasing in speed

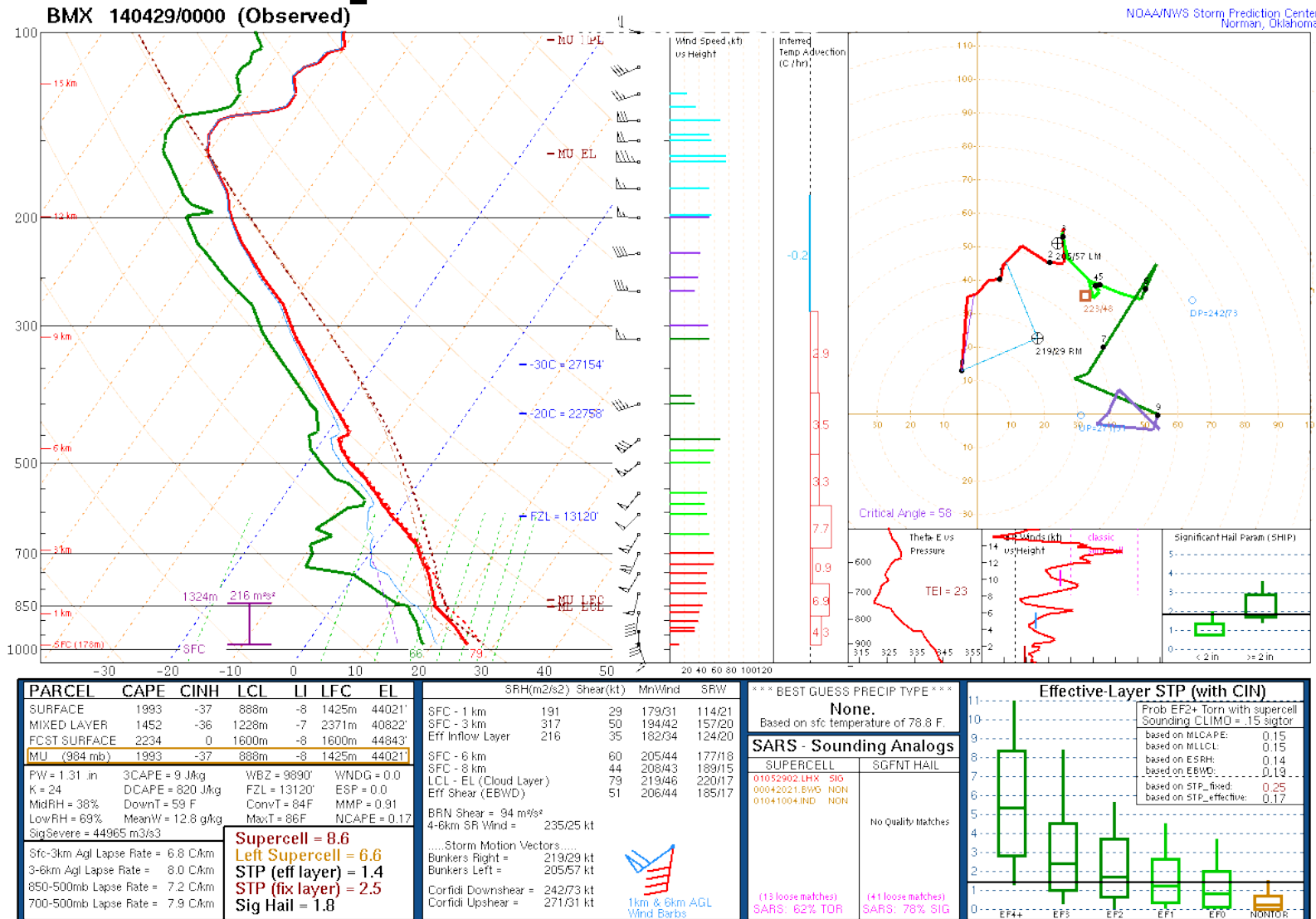
Overall Setup: 12Z/6AM April 28-29, 2014



Surface moisture advecting northward. Instability already present, with capping inversion.

Overall Setup: 00Z/6PM

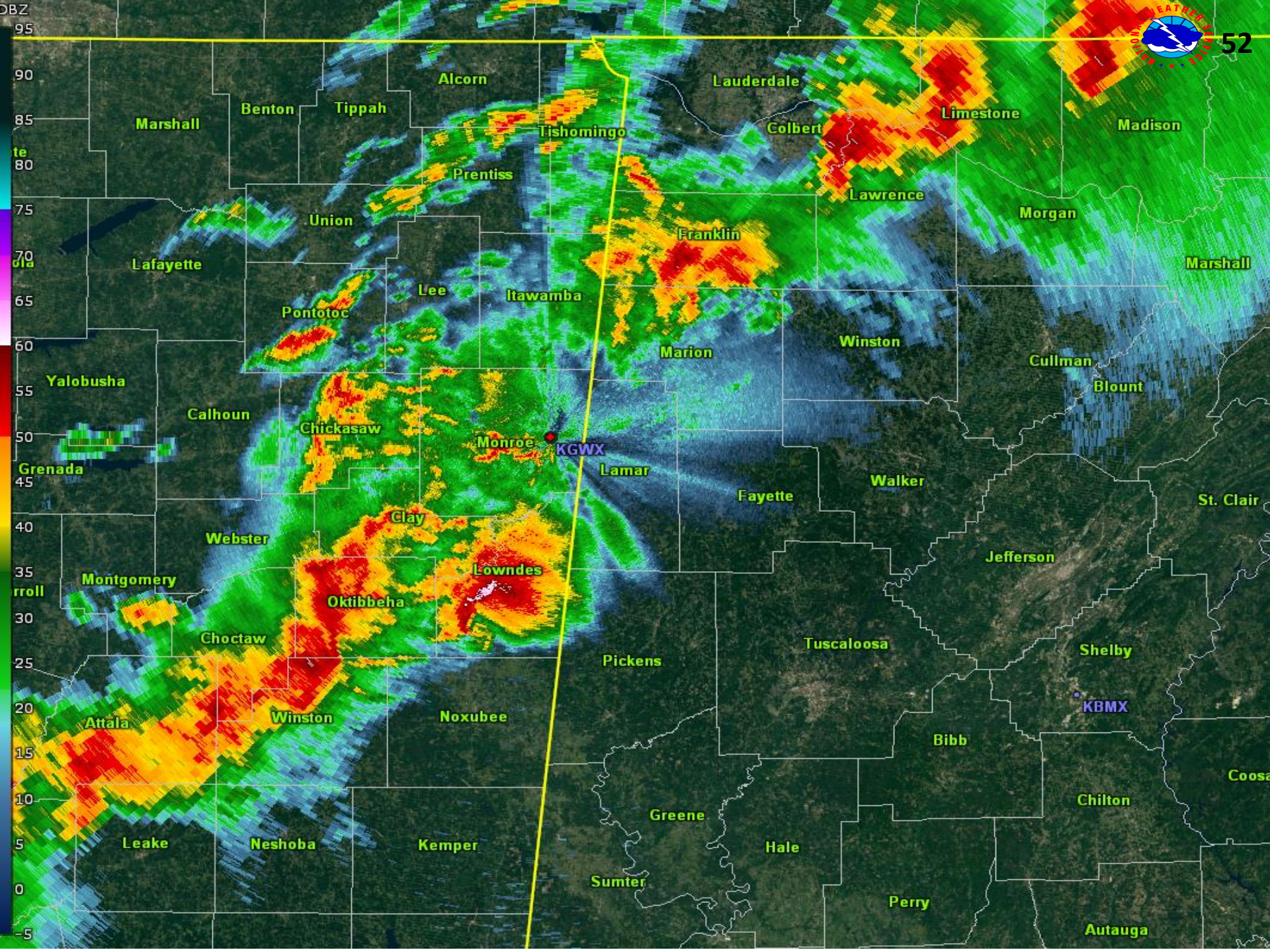
April 28-29, 2014

NOAA/NWS Storm Prediction Center
Norman, Oklahoma


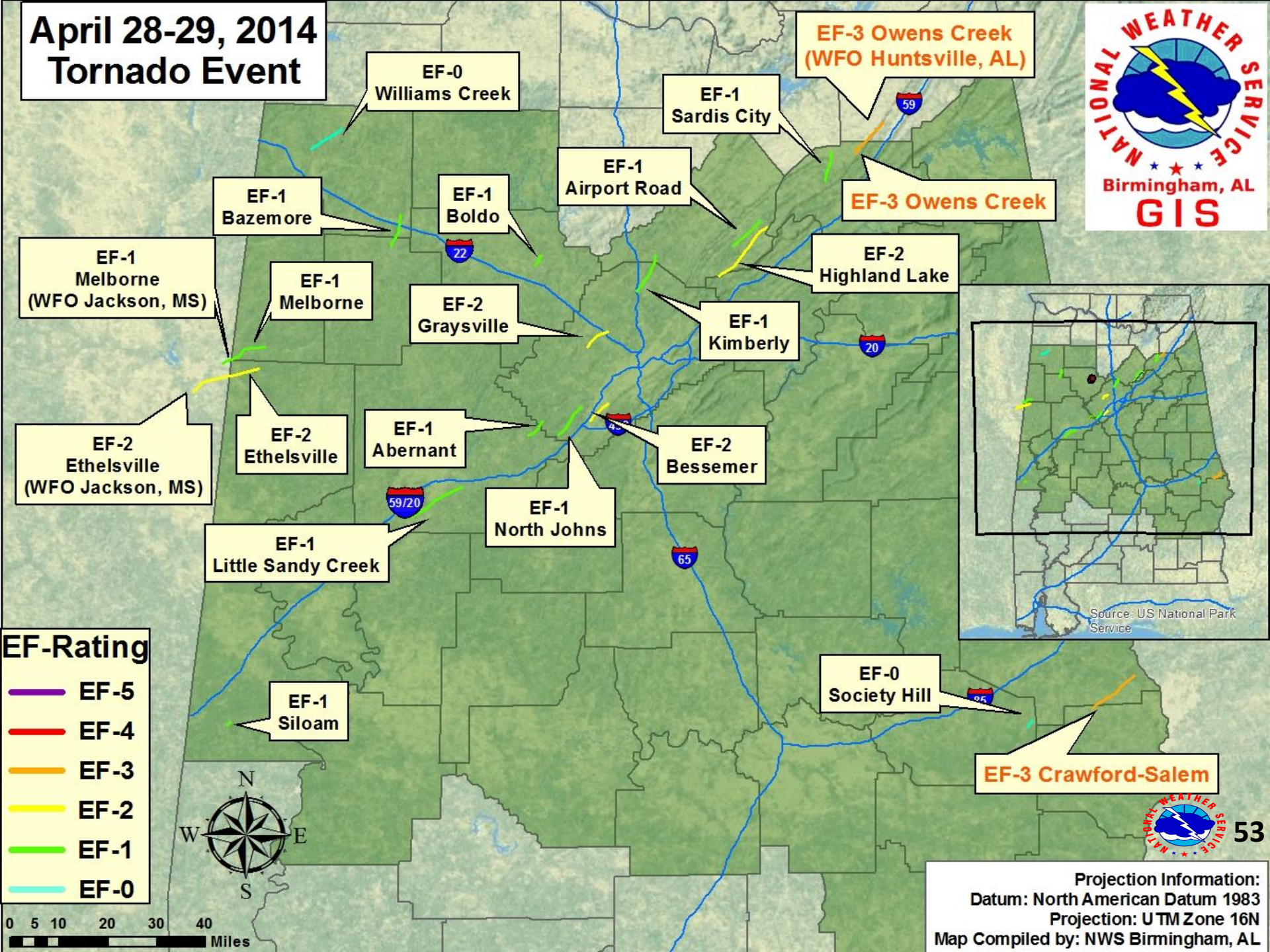



So, What Happened?
April 28-29, 2014





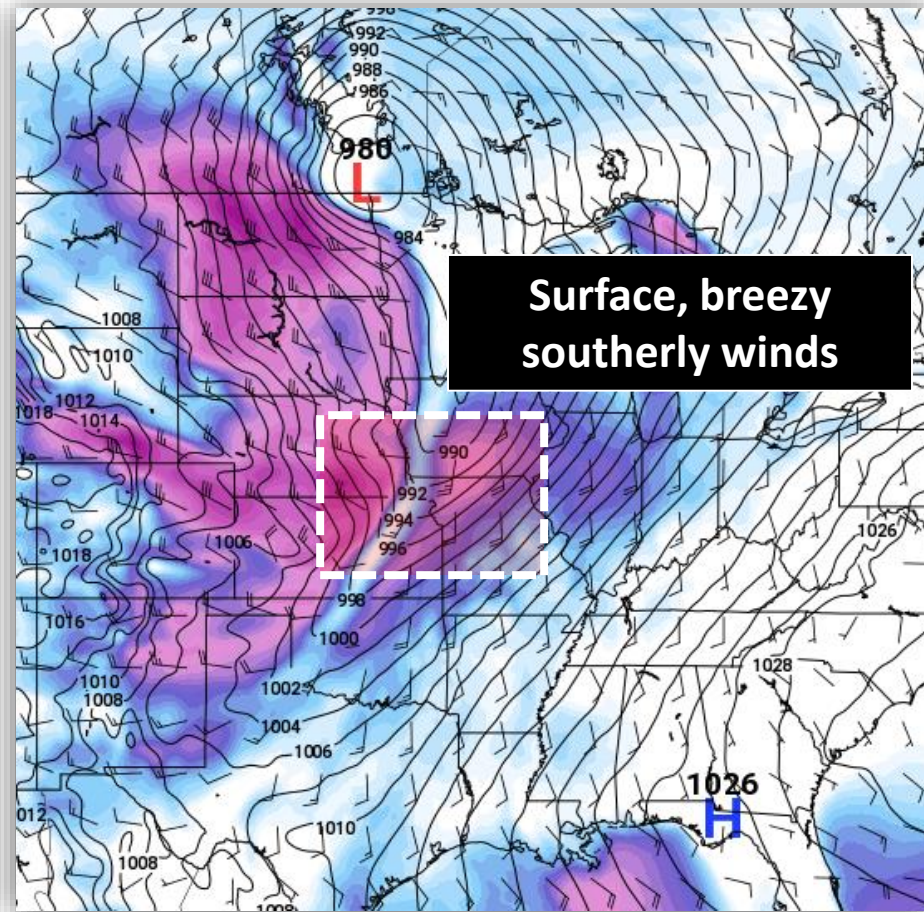
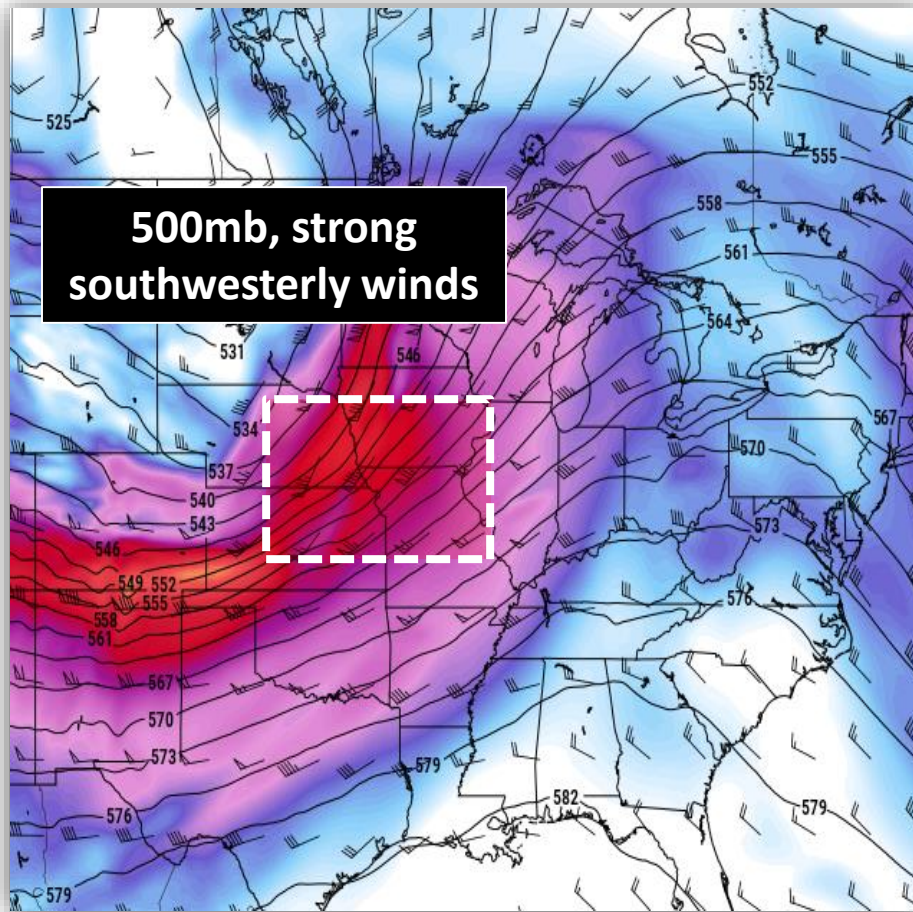
April 28-29, 2014 Tornado Event





Let's Demo an Event!
March 06th 2017

Overall Setup



*Key point: strong, fast-moving cold front approaching!

Overall Setup - Instability

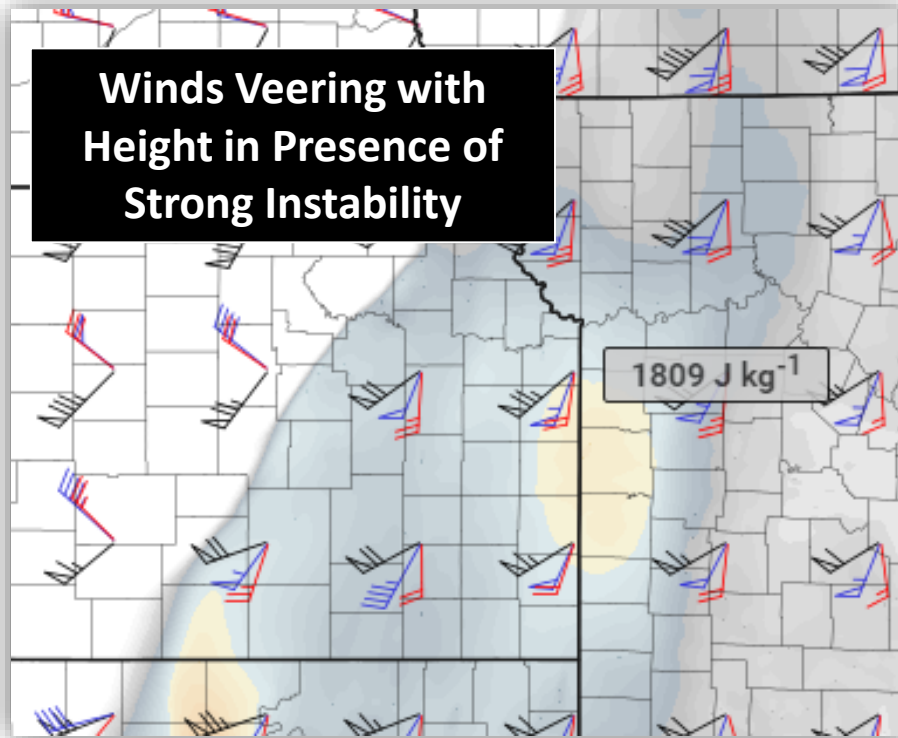
**Surface Moisture
Advecing Northward**

57°F

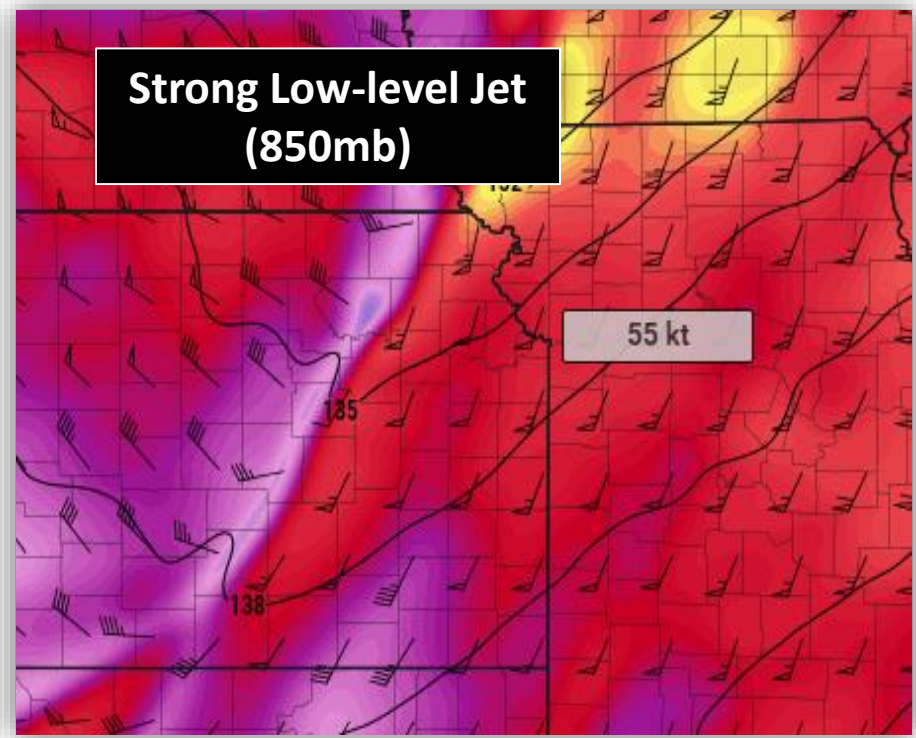
**Surface Warmth
Ahead of Cold Front**

75°F

Overall Setup – Wind Shear



Crossover (kt) at 500 mb, 850 mb, 10 m AGL



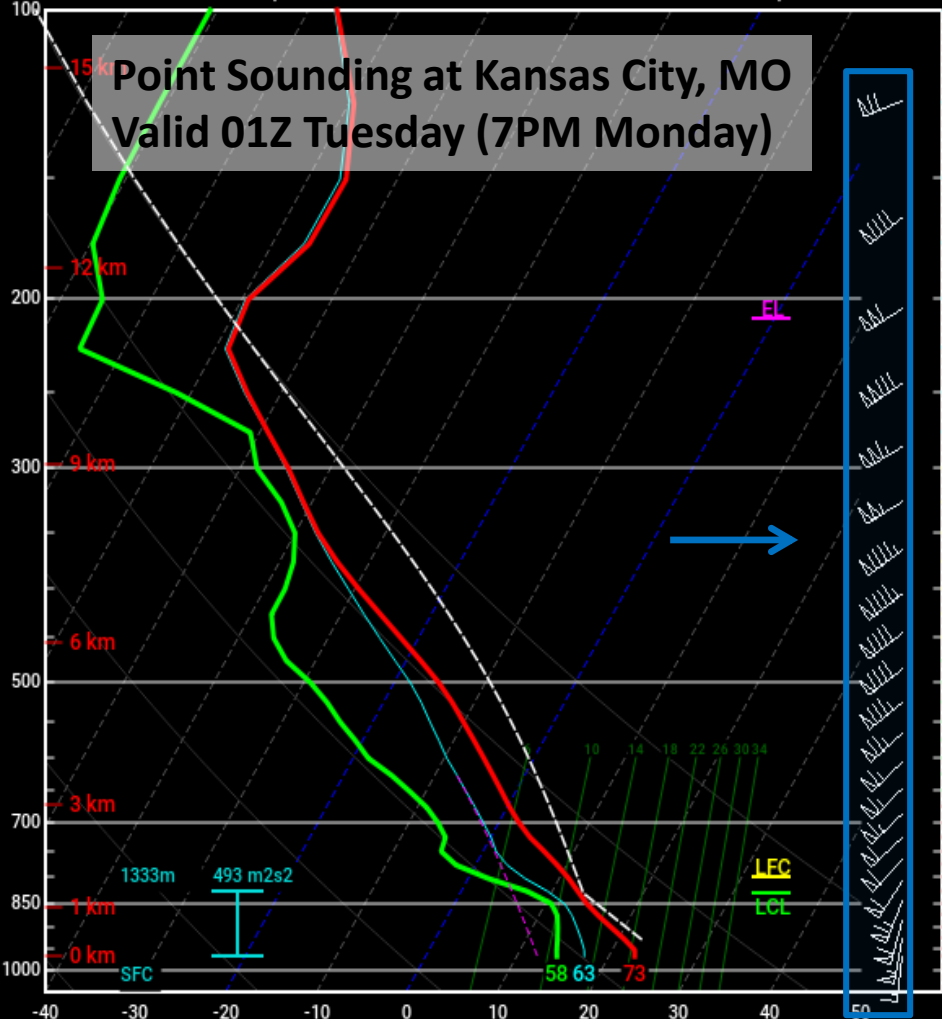
Point Sounding at Kansas City, MO Valid 01Z Tuesday (7PM Monday)

Hodograph



Wind Ingredients for Today:

- Winds veering (turning clockwise) with height
- Surface winds backed (southerly)
- Wind speeds increasing with height
- Strong deep-layer shear
- SRH (storm-relative helicity) favorable for updraft rotation and tornadoes



PCL	CAPE	CINH	LCL	LI	LFC	EL	EH1	SRH	Shear	Mn Wind	SRW	
SFC	1843	-64	1092	-5	1696	11083	SFC-1km	5.4	465	41	194/52	114/38
ML	1946	-18	1301	-5	1643	11230	SFC-3km	6.0	517	49	210/56	126/23
FCST	2564	0	1622	-7	1622	11535	Eff Inflow	5.7	493	43	196/54	118/36
MU	1995	-16	1291	-6	1591	11230	SFC-6km			79	219/61	146/16
PW = 0.94in							SFC-8km			87	221/65	162/14
MeanW = 10.4g/kg							LCL-EL (Cloud Layer)			70	231/77	224/18
LowRH = 65%							Eff Shear (EBWD)			78	218/60	142/16
MidRH = 48%							BRN Shear =		123 m2/s2			
DCAPE = 811							4-6km SR Wind =		222/17 kt			
DwnT = 54F							...Storm Motion Vectors...					
K = 31							Bunkers Right = 233/59 kt					
TT = 56							Bunkers Left = 210/71 kt					
ConvT = 78F							Corfidi Downshear = 246/111 kt					
maxT = 80F							Corfidi Upshear = 275/42 kt					
3CAPE = 114												
SigSvr = 78815 m3/s3												
Sfc-3km AGL LR = 8.1 C/km							Supercell = 19.7					
3-6km AGL LR = 7.2 C/km							STP (cin) = 4.5					
850-500mb LR = 7.4 C/km							STP (fix) = 5.2					
700-500mb LR = 6.8 C/km							SHIP = 1.5					
							1km & 6km AGL Wind Barbs					

PW = 0.94in
MeanW = 10.4g/kg
LowRH = 65%
MidRH = 48%
DCAPE = 811
DownT = 54F

K = 31
TT = 56
ConvT = 78F
maxT = 80F
ESP = 2.5
MMP = 1.0

WINDG = 1.5
TEI = 18
3CAPE = 114
SigSvr = 78815 m3/s3

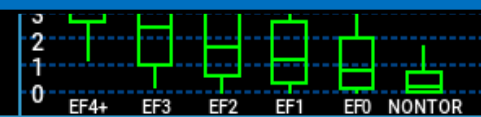
Sfc-3km AGL LR = 8.1 C/km
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700-500mb LR = 6.8 C/km

Supercell = 19.7
STP (cin) = 4.5
STP (fix) = 5.2
SHIP = 1.5

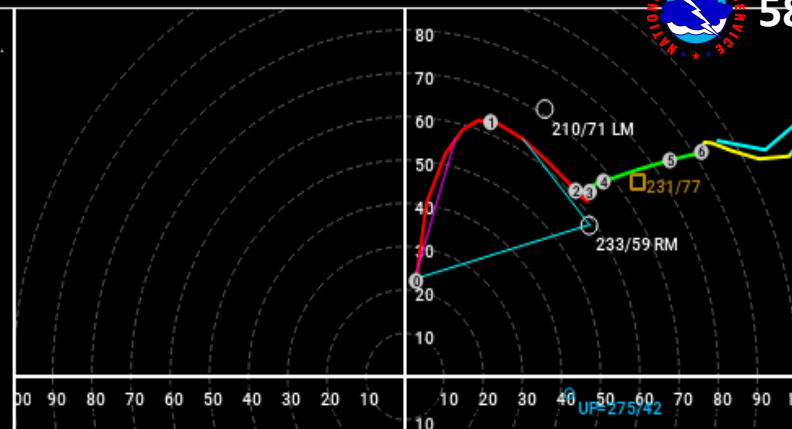
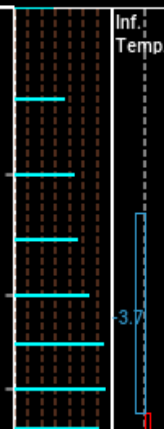
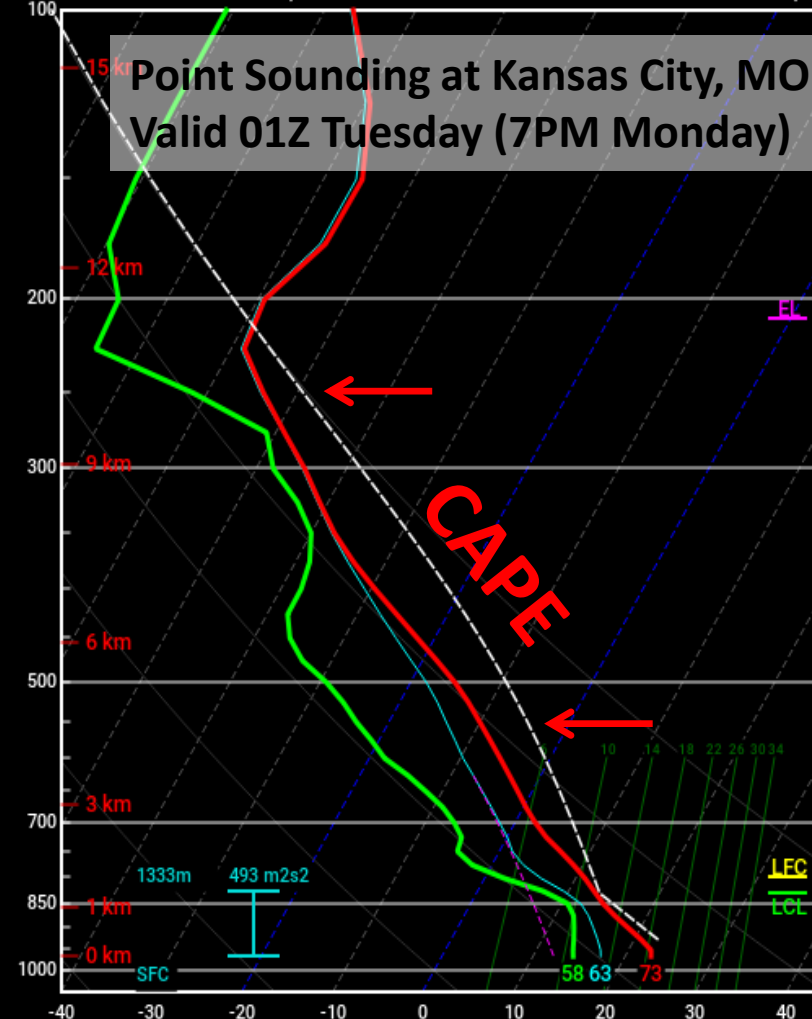


(3 loose matches)
SARS: 67% TOR

(16 loose matches)
SARS: 94% SIG



Point Sounding at Kansas City, MO Valid 01Z Tuesday (7PM Monday)



Energy Ingredients for Today:

- Moderate surface-based CAPE
- Moderate mixed-layer CAPE
- A touch of capping
- Steep low- and mid-level lapse rates
- Largely-negative LI
- Sufficient moisture

PCL	CAPE	CINH	LCL	LI	LFC	EL
SFC	1843	-64	1092	-5	1696	11083
ML	1946	-18	1301	-5	1643	11230
FCST	2564	0	1622	-7	1622	11535
MU	1995	-16	1291	-6	1591	11230

PW = 0.94in
MeanW = 10.4g/kg
LowRH = 65%
MidRH = 48%
DCAPE = 811
DownT = 54F

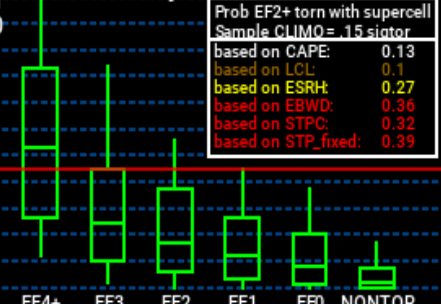
EH1	SRH	Shear	MnWind	SRW
SFC-1km	5.4	465	41	194/52
SFC-3km	6.0	517	49	210/56
Eff Inflow	5.7	493	43	196/54
SFC-6km			79	219/61
SFC-8km			87	221/65
LCL-EL (Cloud Layer)			70	231/77
Eff Shear (EBWD)			78	218/60
BRN Shear =		123 m2/s2		
4-6km SR Wind =		222/17 kt		

...Storm Motion Vectors...
Bunkers Right = 233/59 kt
Bunkers Left = 210/71 kt
Corfidi Downshear = 246/111 kt
Corfidi Upshear = 275/42 kt

SARS - Sounding Analogs

SUPERCELL	SGFNT HAIL
No Quality Matches	No Quality Matches
(3 loose matches) SARS: 67% TOR	(16 loose matches) SARS: 94% SIG

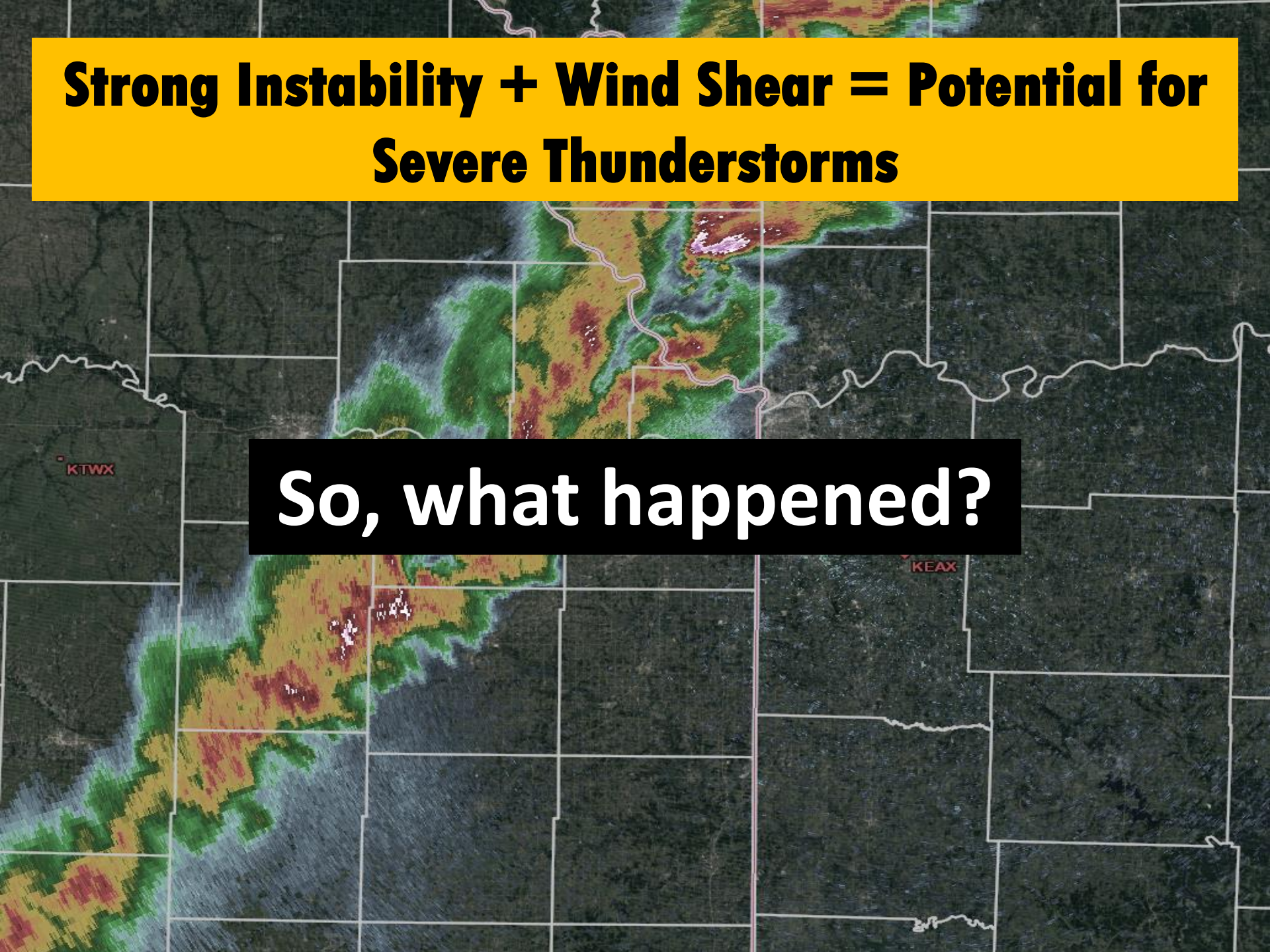
Effective Layer STP (with CIN)

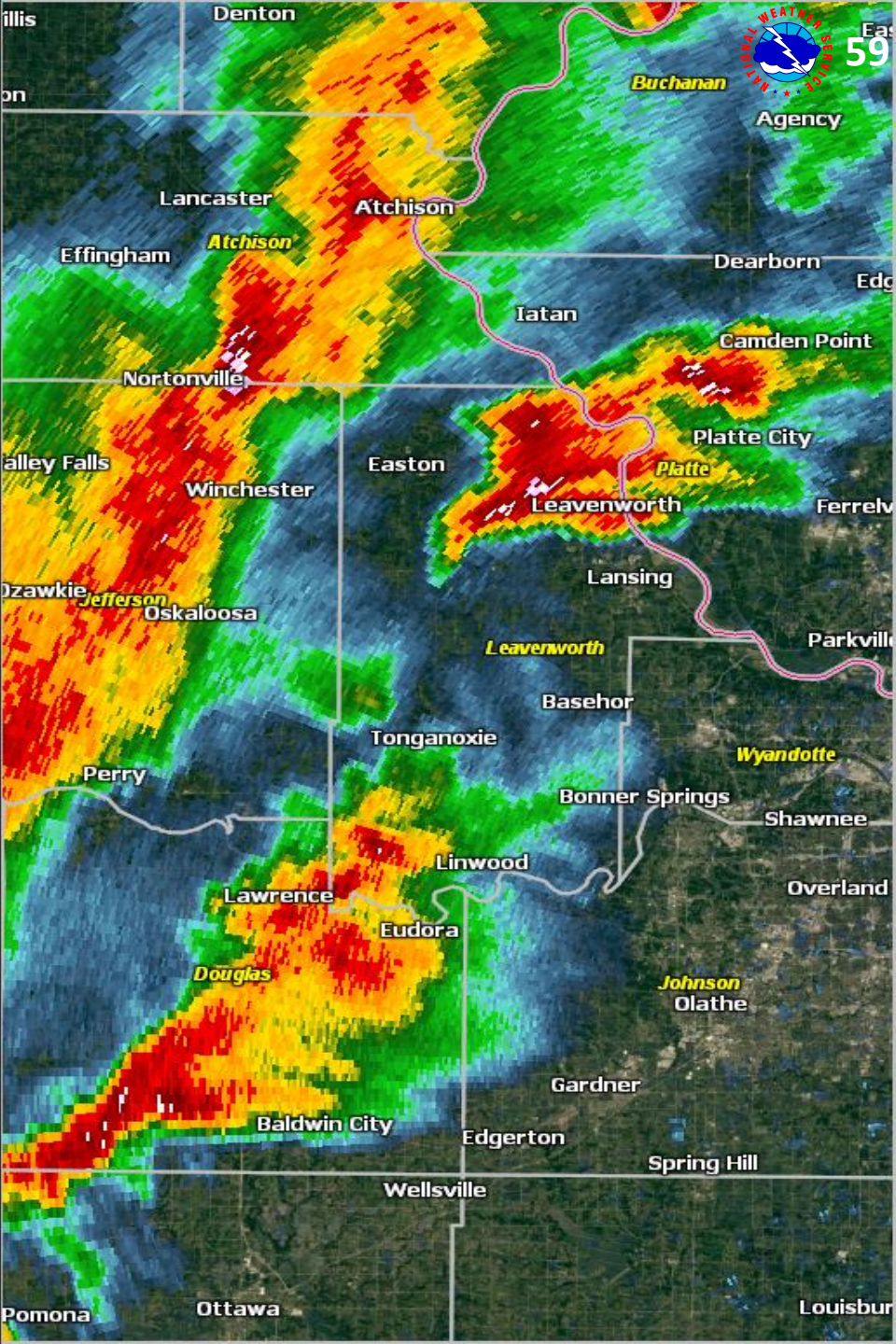
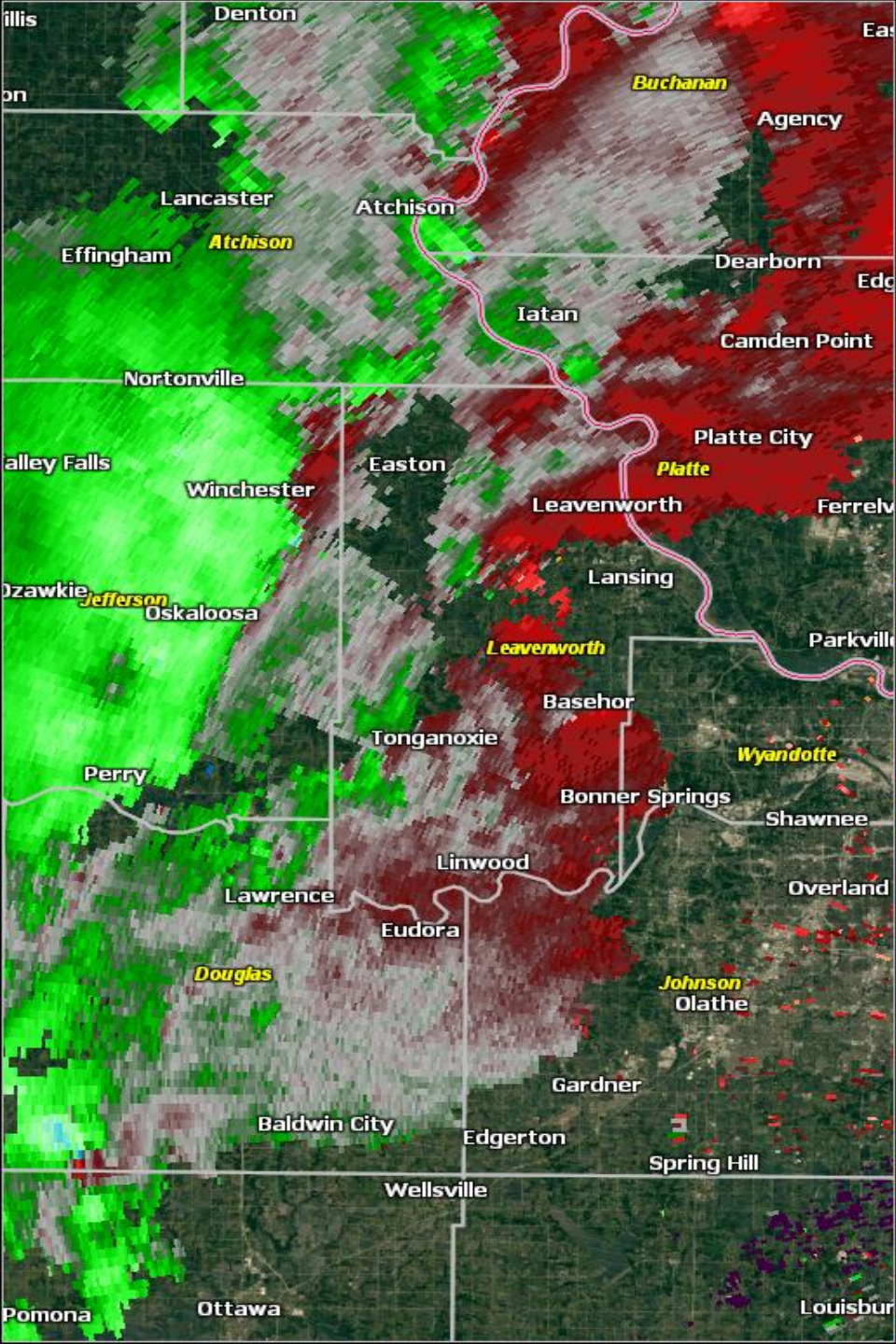


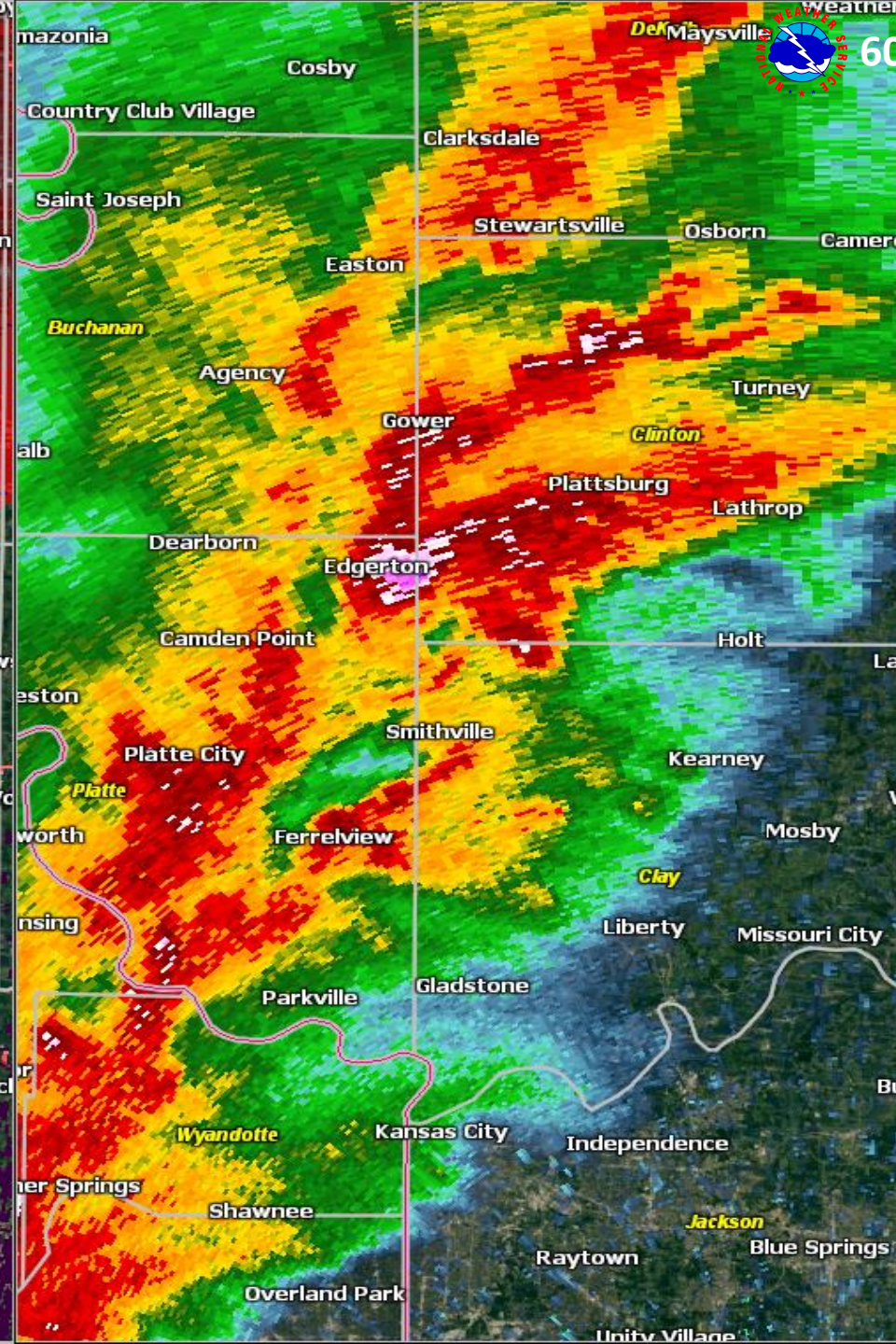
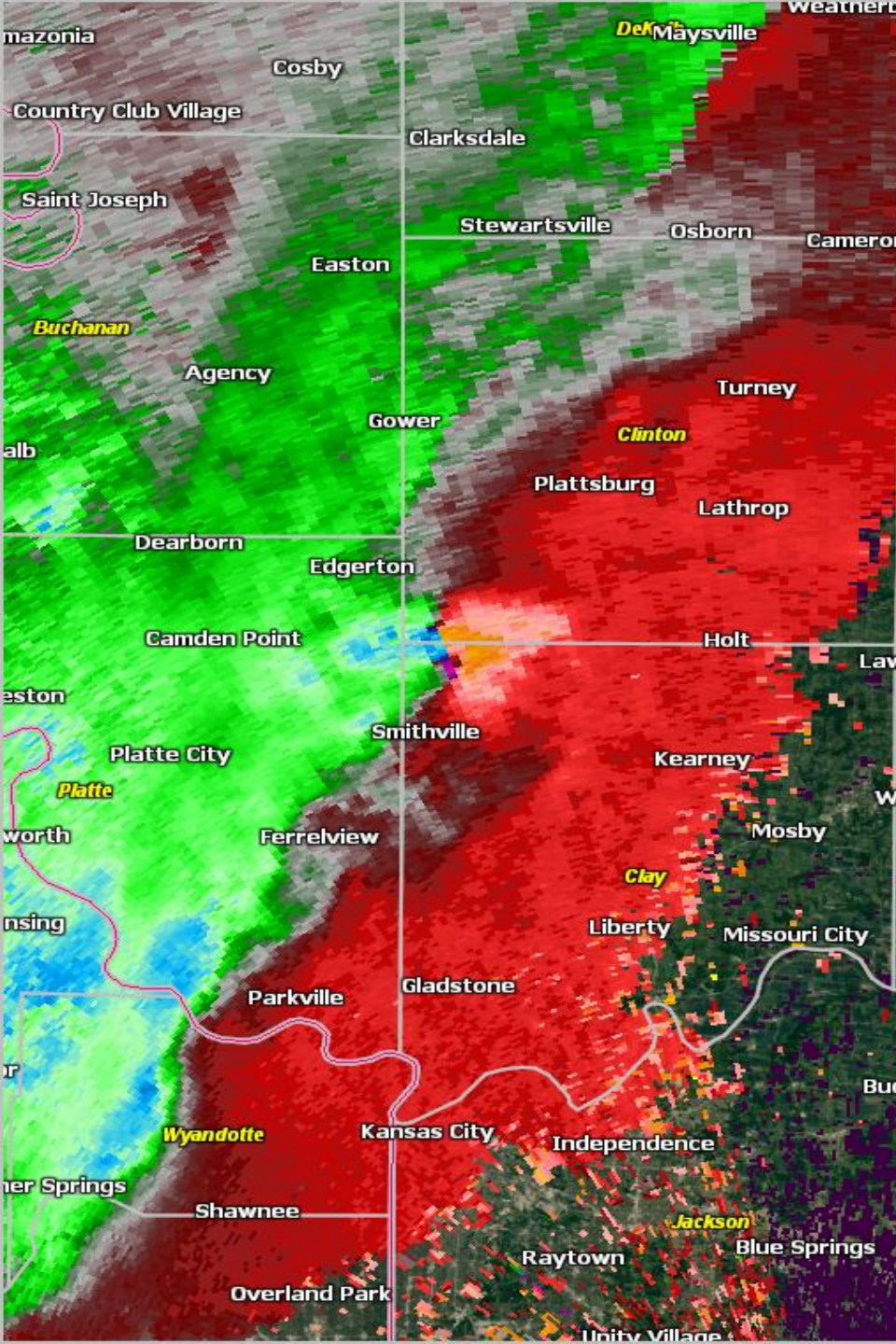
Prob EF2+ torn with supercell
Sample CLIM0 = 15 sinter
based on CAPE: 0.13
based on LCL: 0.1
based on ESRH: 0.27
based on EBWD: 0.36
based on STPC: 0.32
based on STP_fixed: 0.39

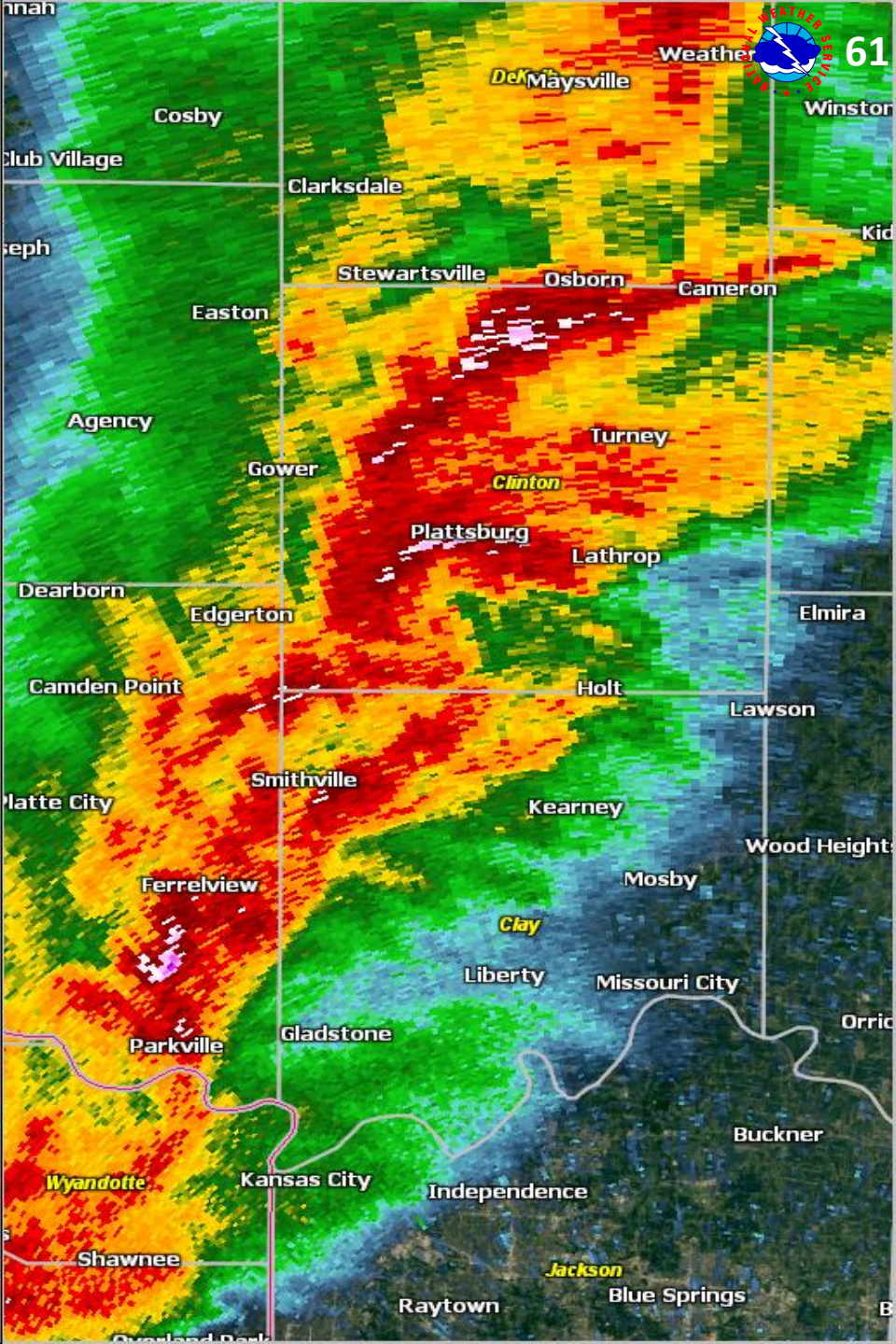
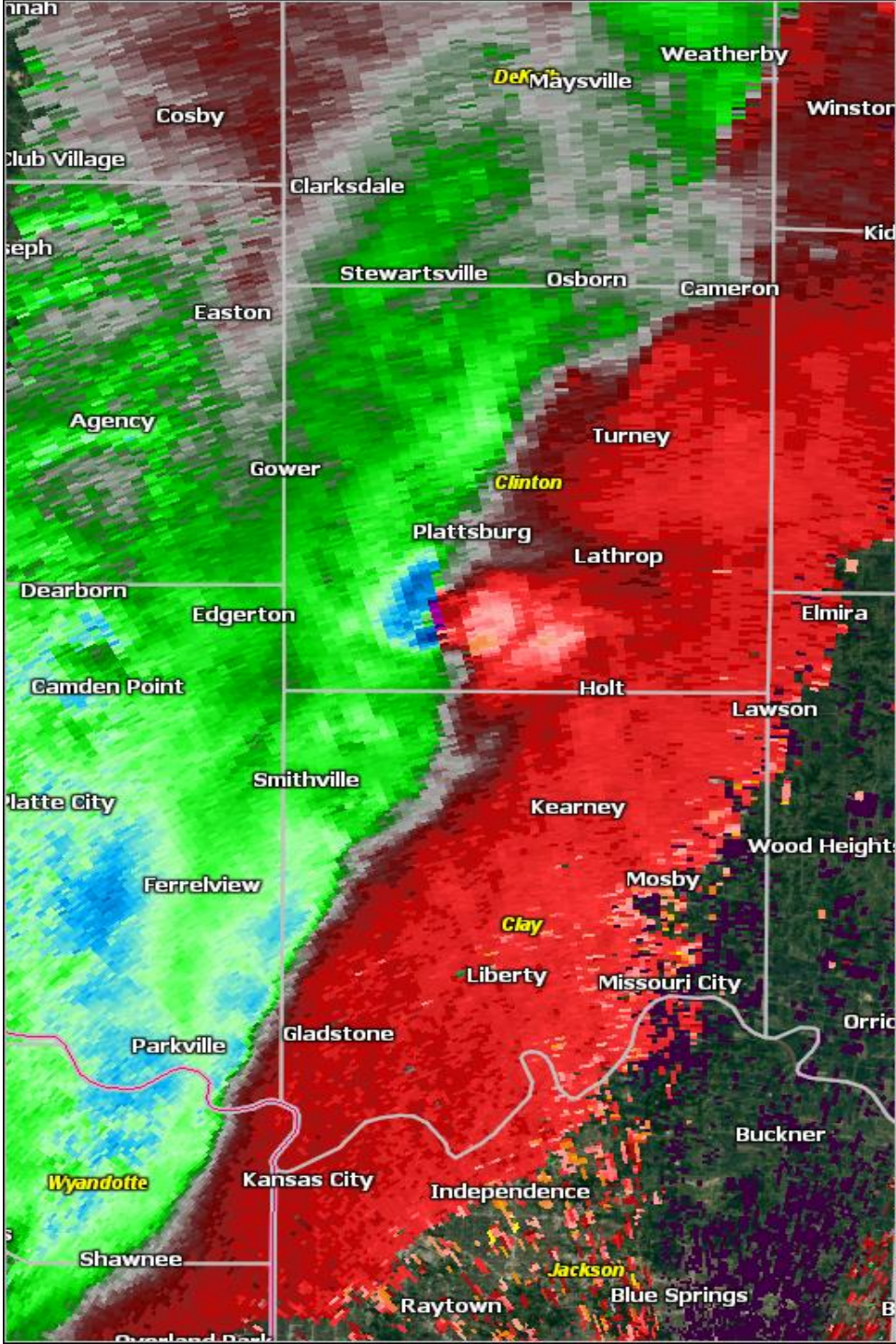
**Strong Instability + Wind Shear = Potential for
Severe Thunderstorms**

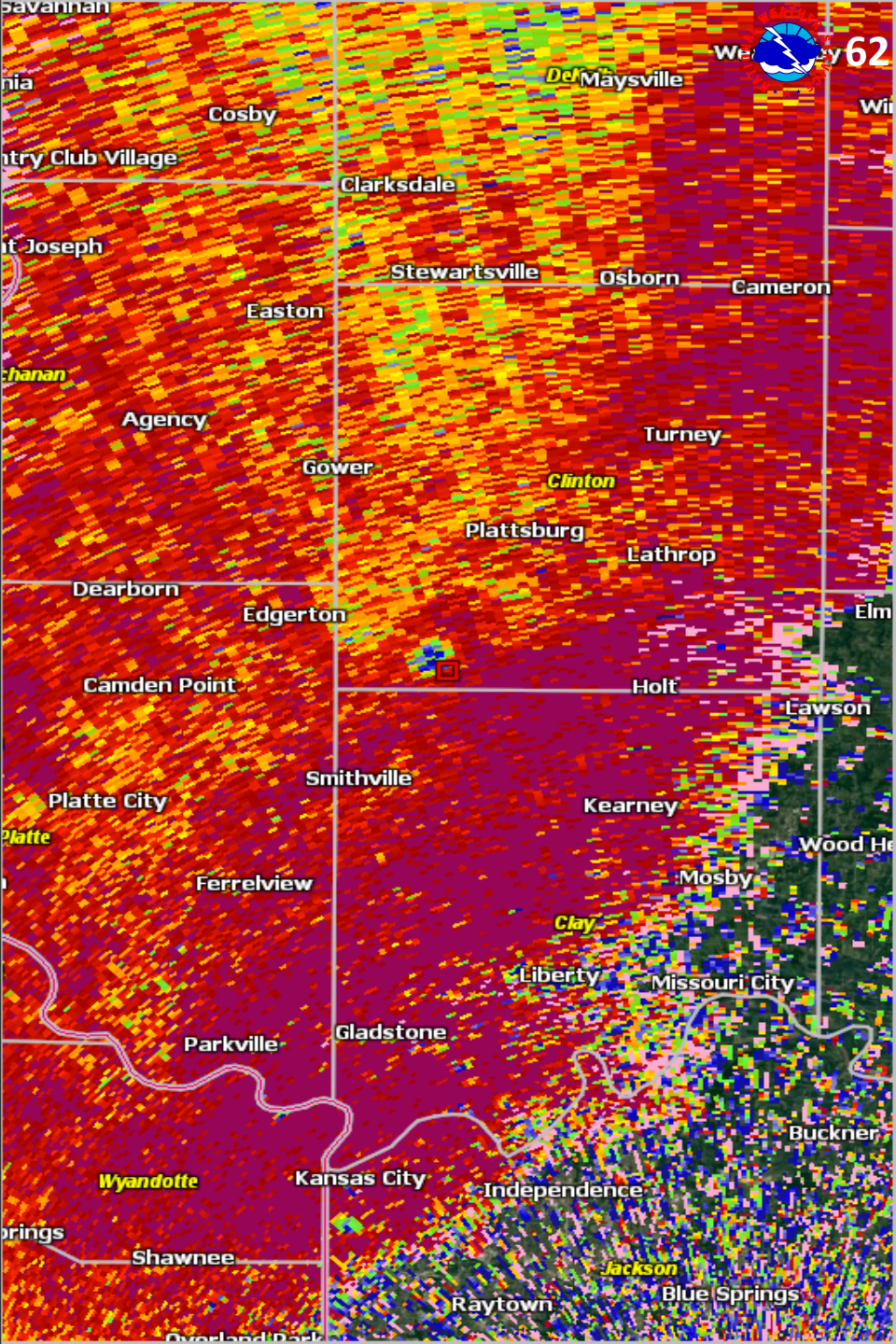
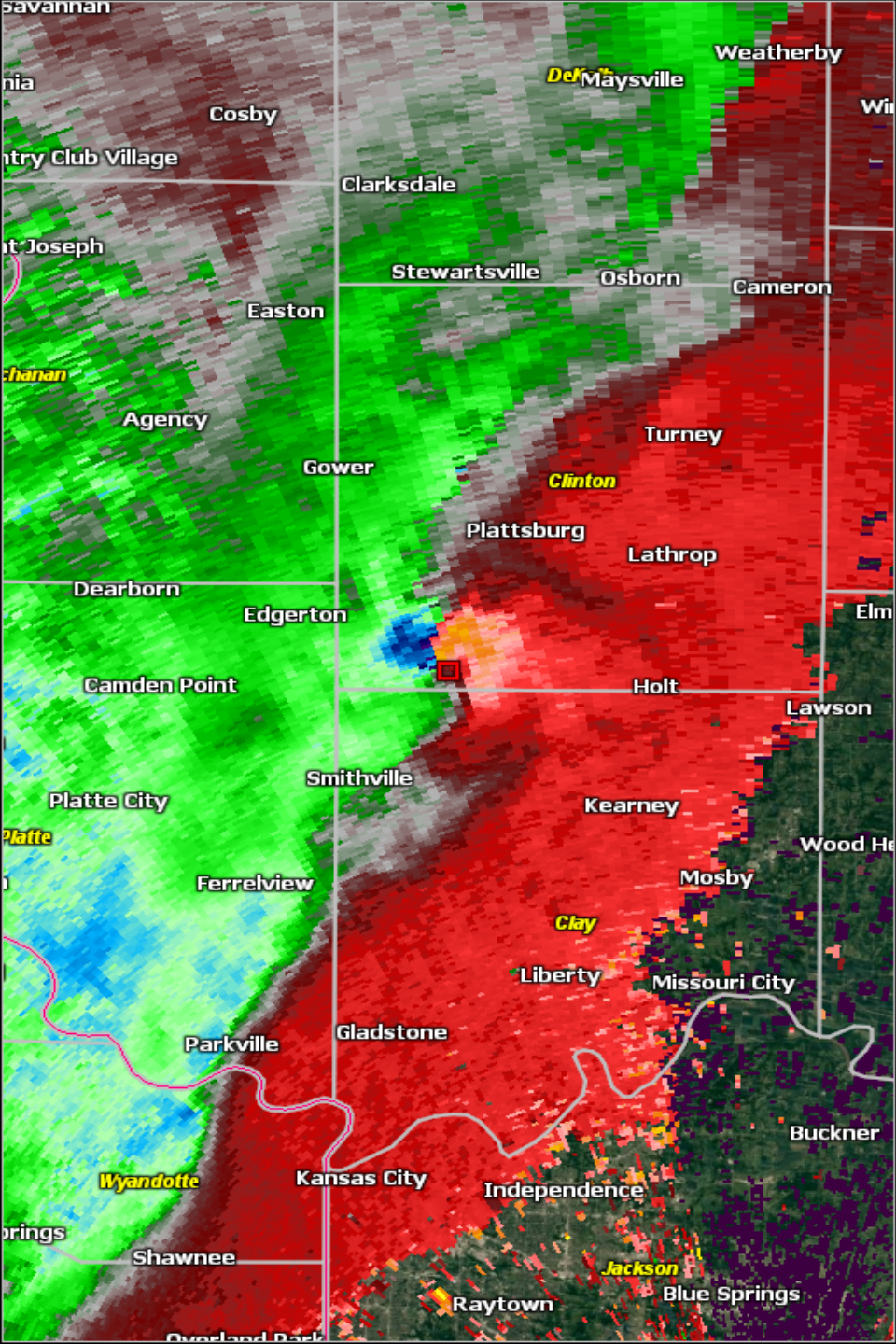
So, what happened?

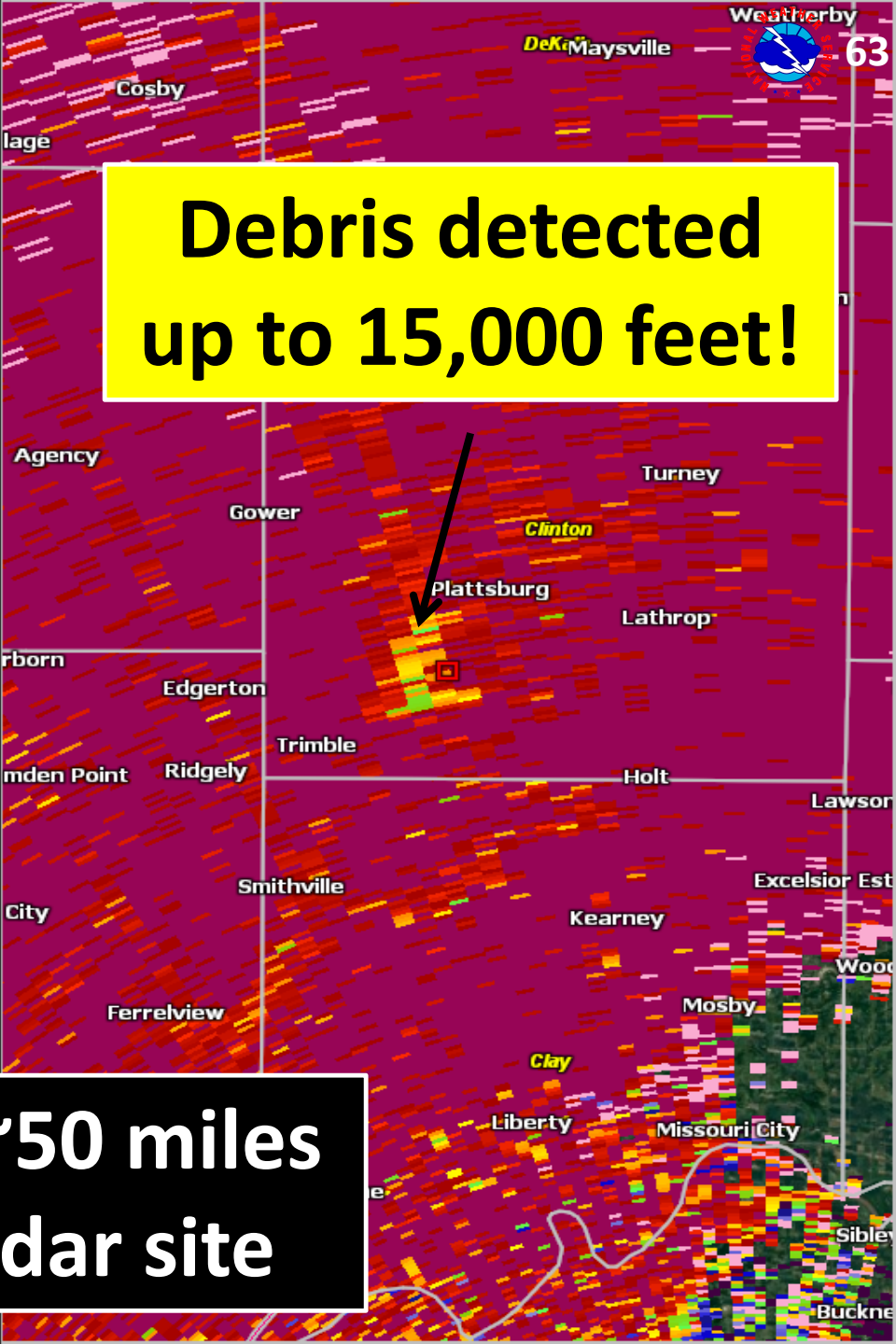
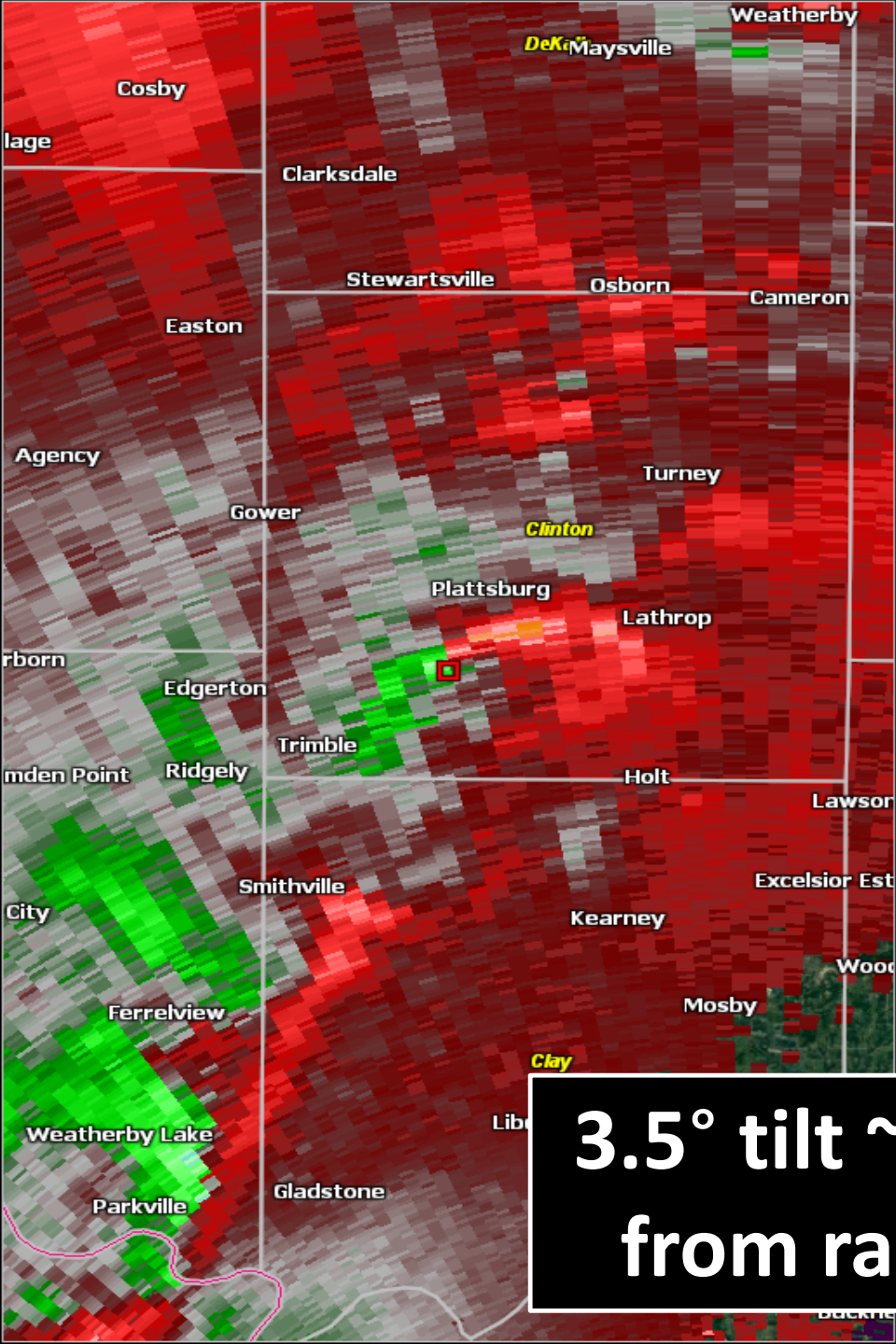












**3.5° tilt ~50 miles
from radar site**

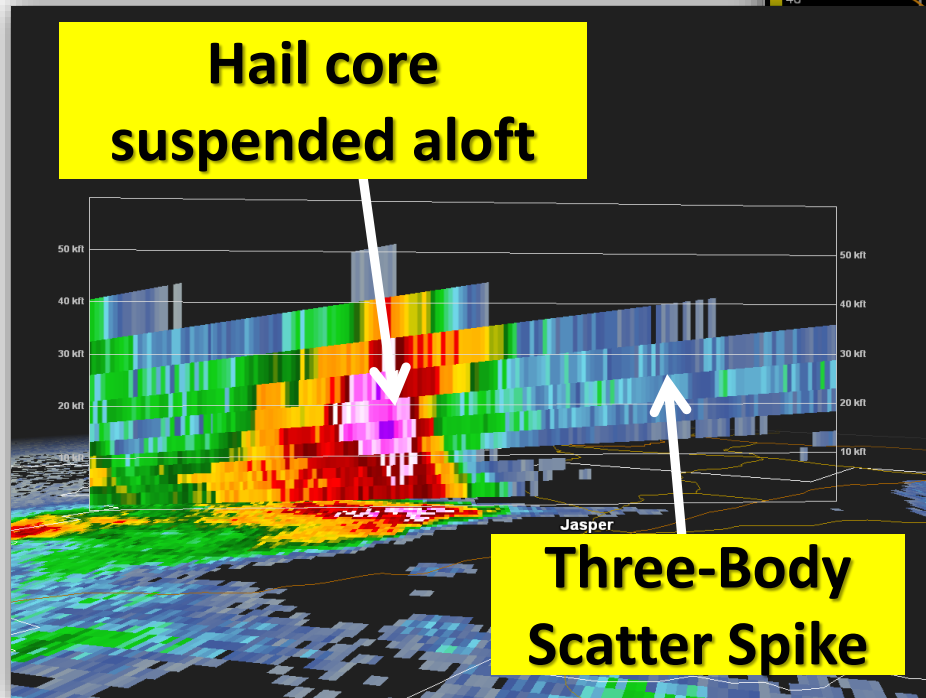
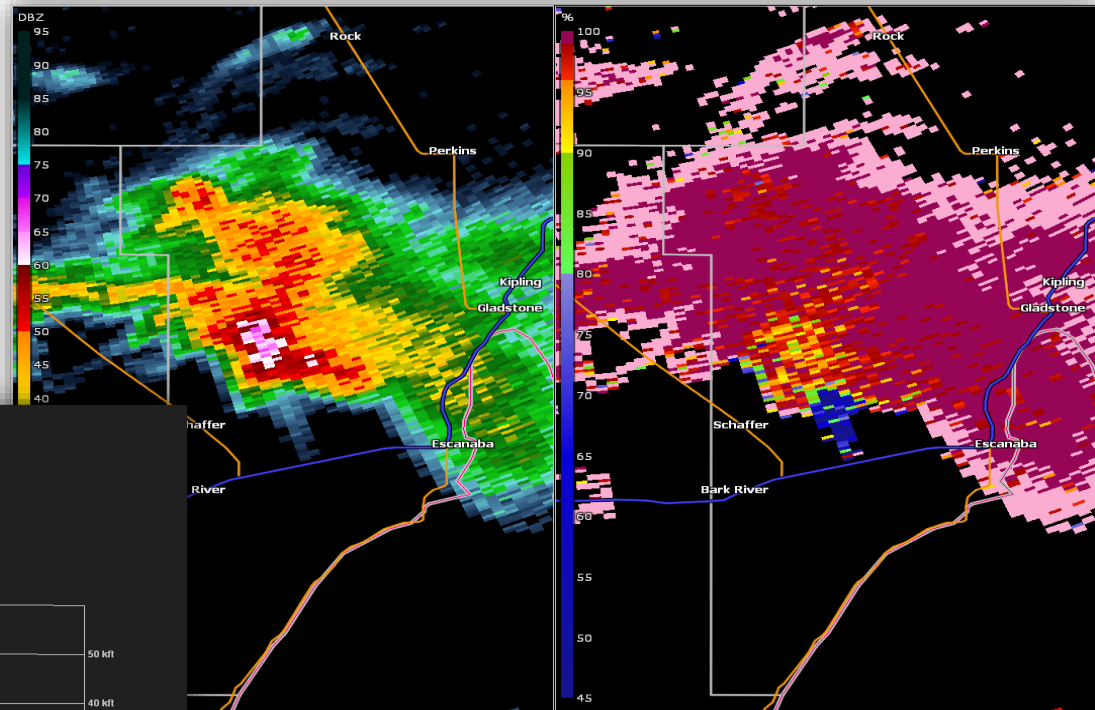
Reflectivity

Velocity

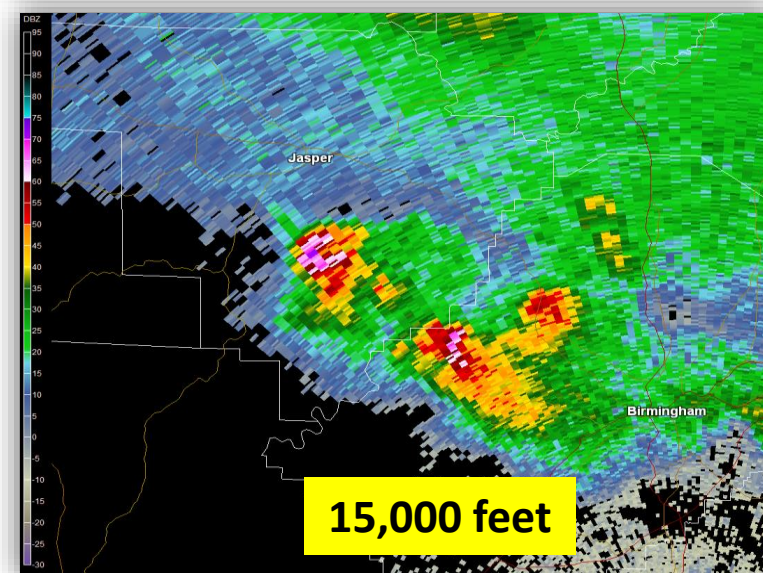
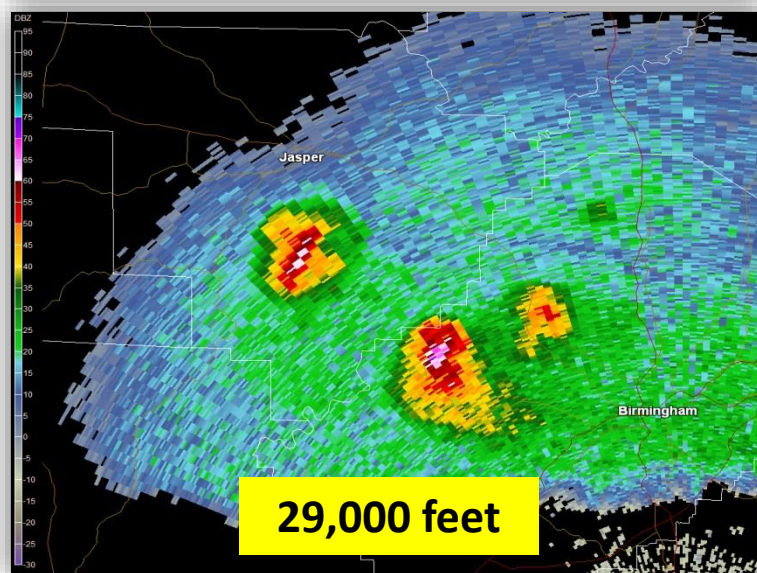
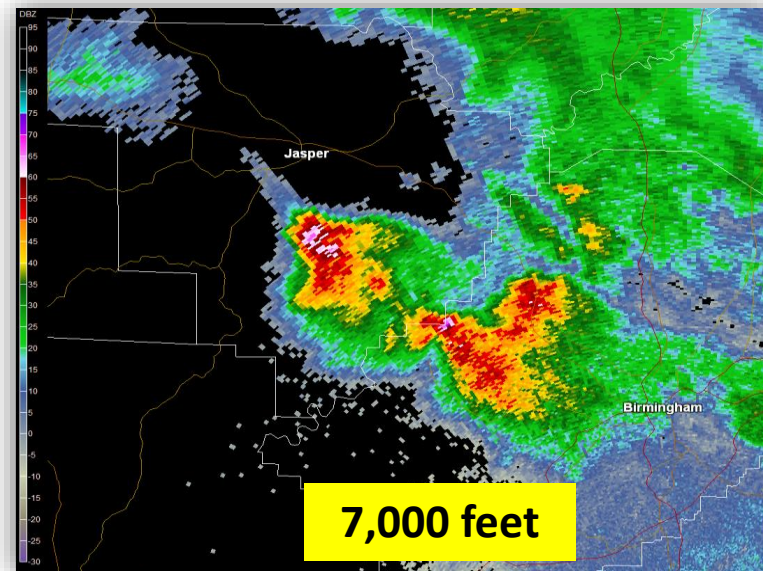
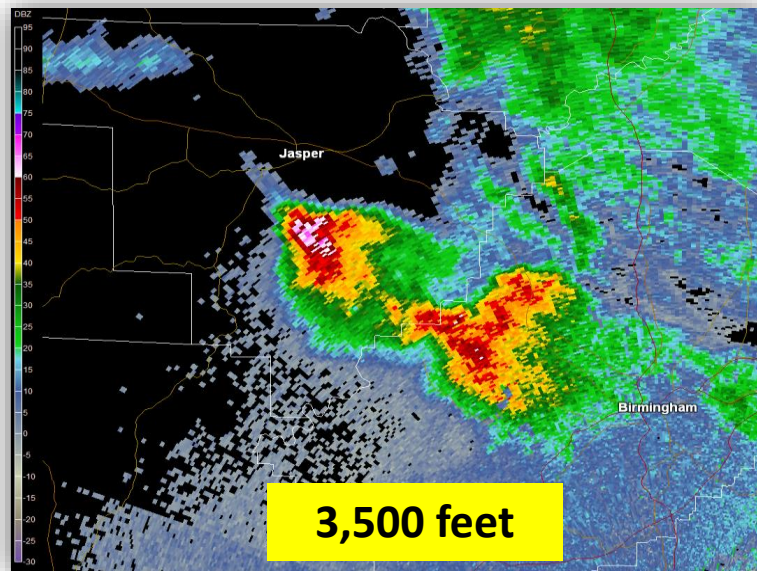
'Out the Window'

Gerald Satterwhite

Three-Body Scatter Spike



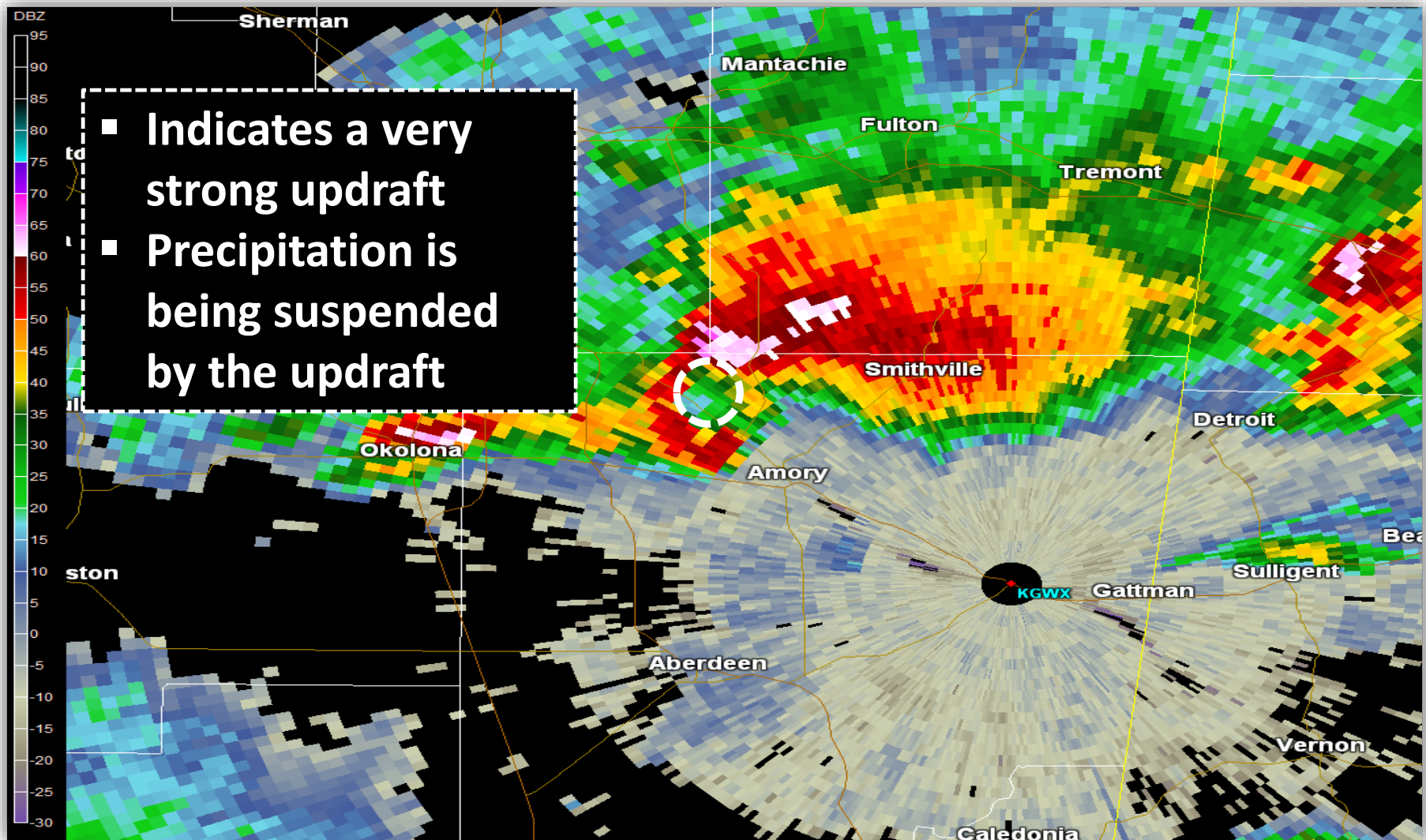
Three-Body Scatter Spike; Hail Core at X Feet



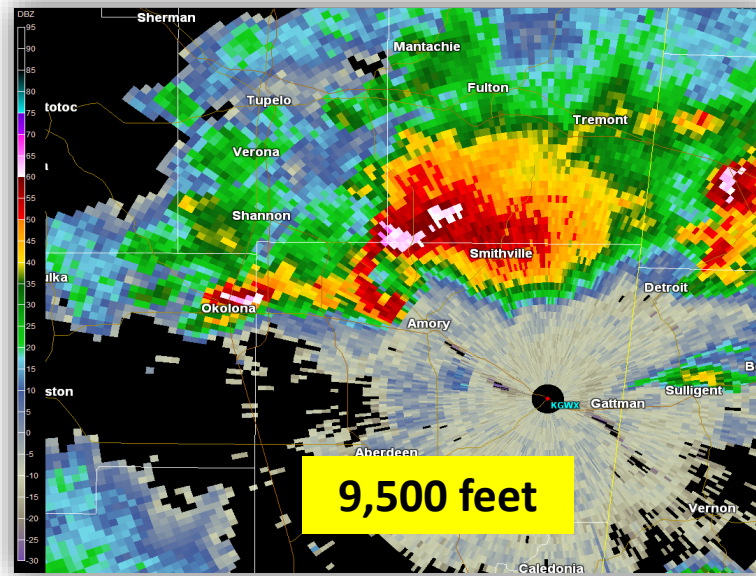
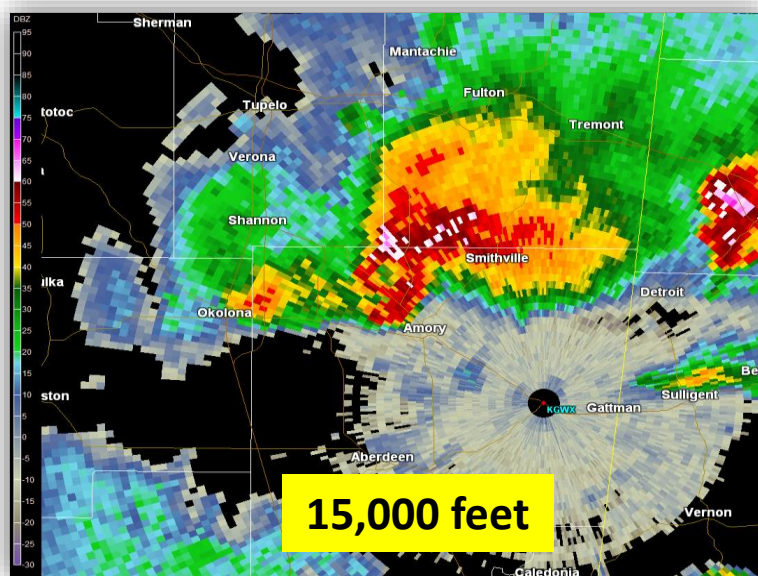
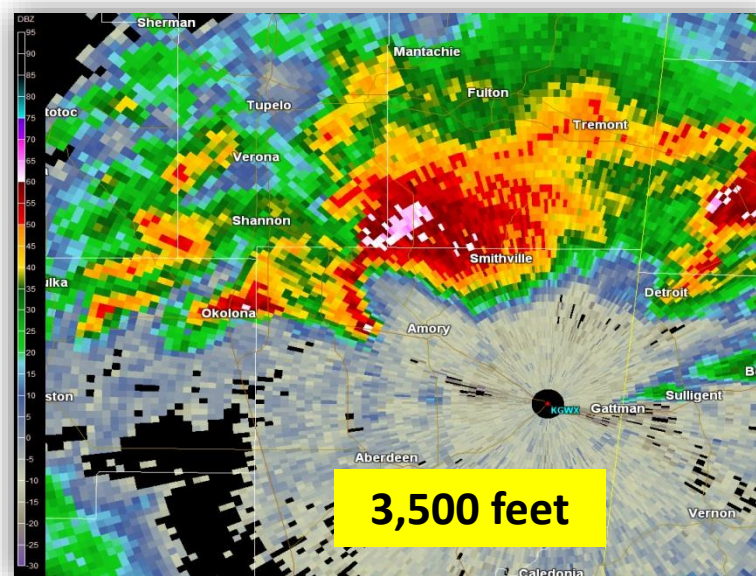
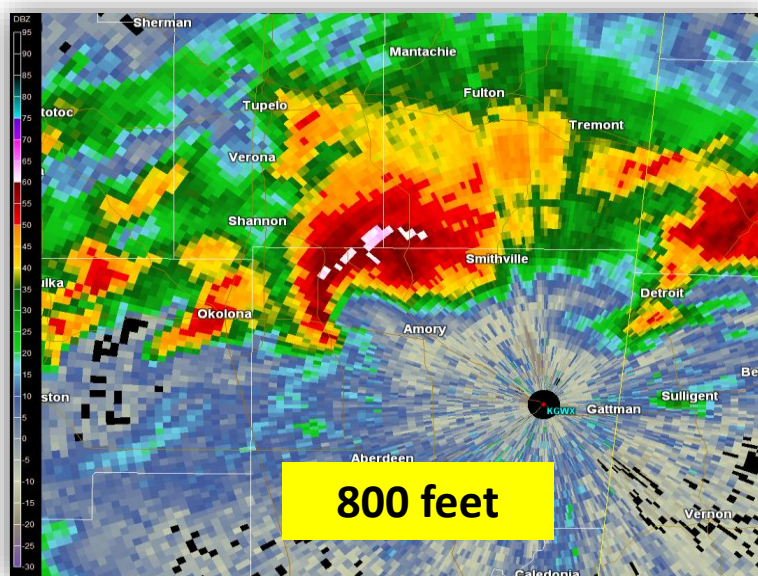
Vertical Wind Speed for Different Hail Sizes (updraft speeds)

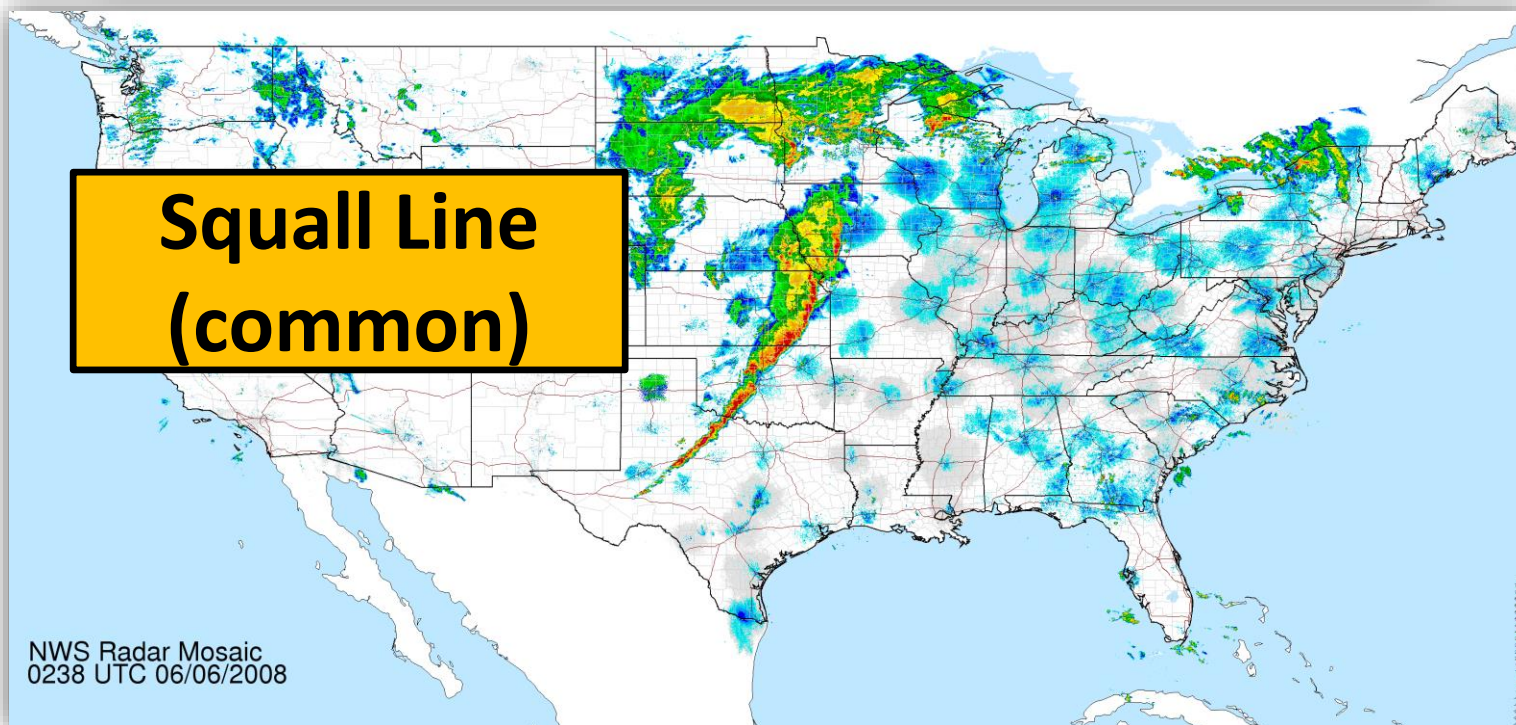
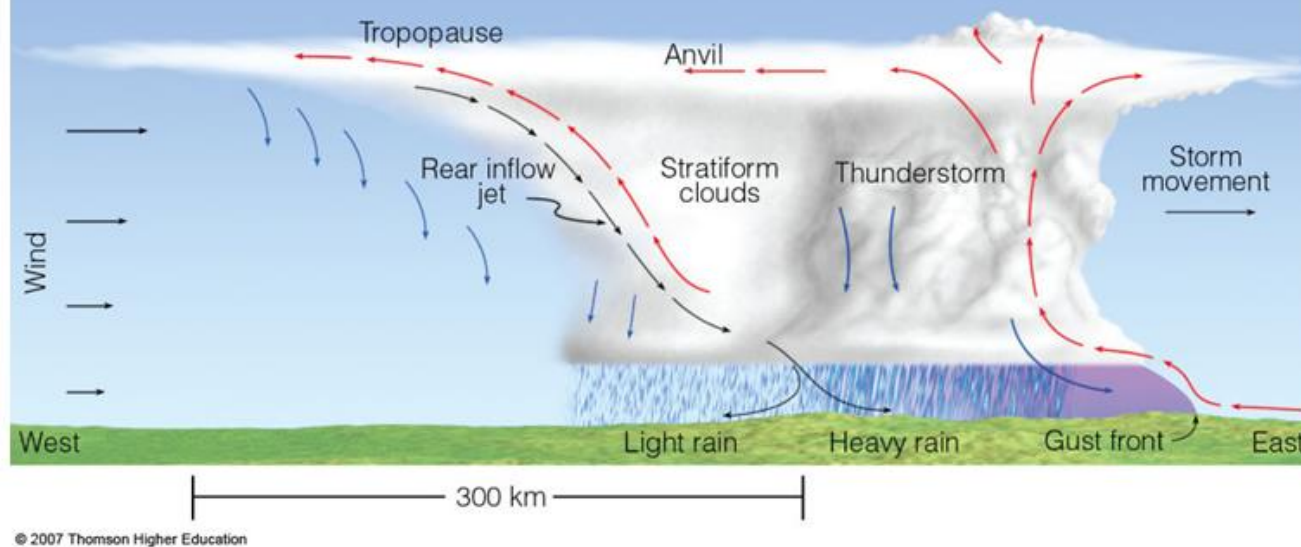
Hailstone size	Measurement		Updraft Speed	
	in.	cm.	mph	km/h
bb	< 1/4	< 0.64	< 24	< 39
pea	1/4	0.64	24	39
	1/2	1.3	35	56
dime	7/10	1.8	38	61
penny	3/4	1.9	40	64
nickel	7/8	2.2	46	74
quarter	1	2.5	49	79
half dollar	1 1/4	3.2	54	87
walnut	1 1/2	3.8	60	97
golf ball	1 3/4	4.4	64	103
hen egg	2	5.1	69	111
tennis ball	2 1/2	6.4	77	124
baseball	2 3/4	7.0	81	130
tea cup	3	7.6	84	135
grapefruit	4	10.1	98	158
softball	4 1/2	11.4	103	166

Bounded Weak Echo Region (BWER)



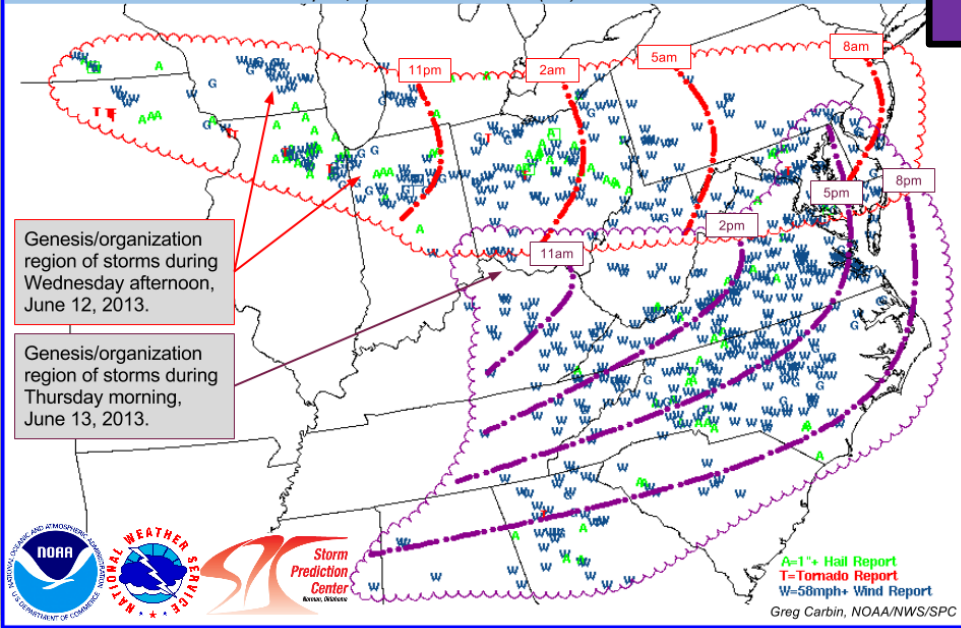
BWER at X Feet Above Ground Level



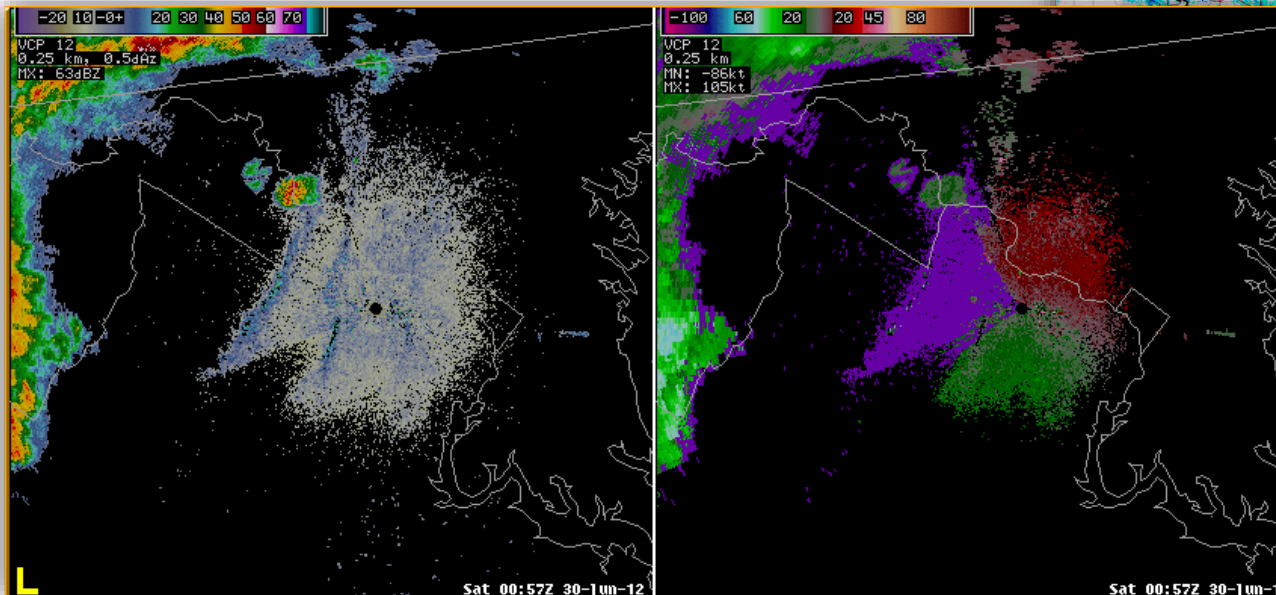
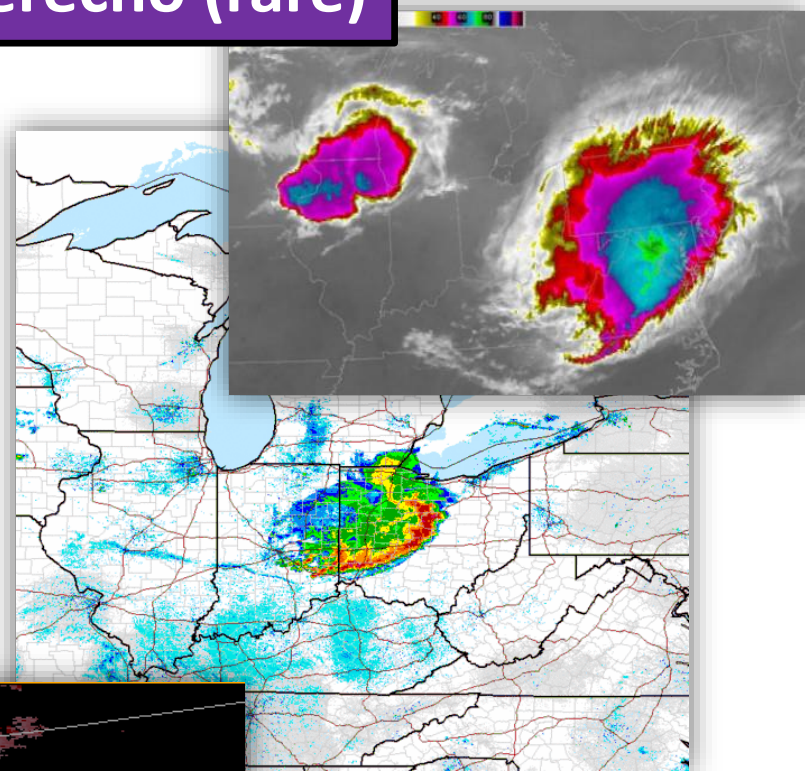


June 12 and 13, 2013 Severe Wind/Derecho Events Midwest and Mid Atlantic

Reports, squall line location and time (EDT): —•—•—



Derecho (rare)



- Damaging winds over swath of 250+ miles
- Concentrated and persistent area of severe winds, damage
- Maintained over 6+ hour duration

Below the Radar Beam?

Spotters Help Tell the Story



Radar tells us the storm is capable of producing strong winds, hail, and/or a tornado

Spotters help confirm if the storm is producing damaging winds, hail, and/or a tornado

Important Definitions



OUTLOOK

Anticipated weather hazards during the next 7 days.
Issued daily and updated as needed.
[Keep Tabs] ... Ready



WATCH

Atmospheric conditions are favorable, or could become favorable, for the development of thunderstorms which could produce severe weather.
[Remain Alert] ... Set

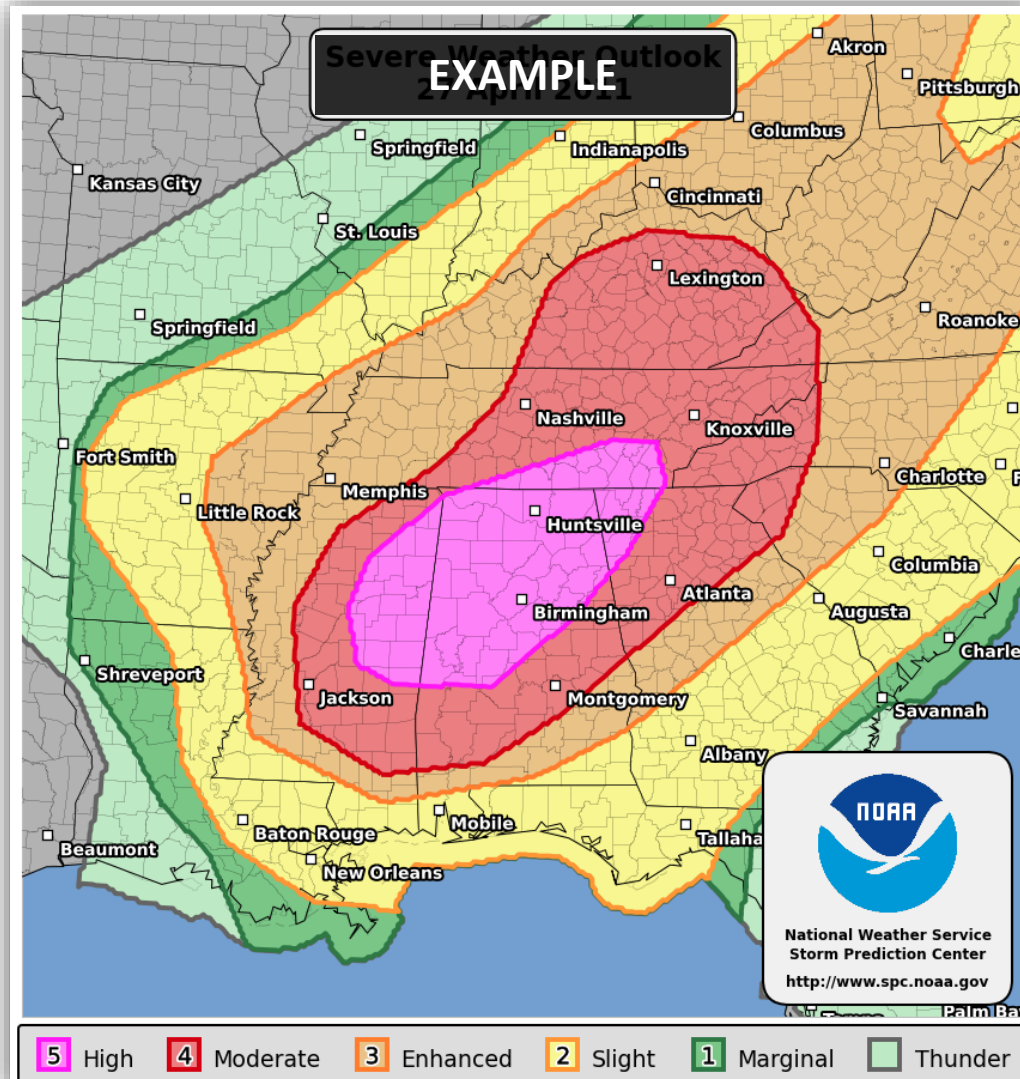


WARNING

Severe weather is occurring, or is likely to occur.
[Take protective action] ... GO!

Storm Prediction Center (SPC)


Convective Outlook



Storm Prediction Center

Severe Weather Outlook

Understanding Severe Thunderstorm Risk Categories

THUNDERSTORMS (no label)	1 - MARGINAL (MRGL)	2 - SLIGHT (SLGT)	3 - ENHANCED (ENH)	4 - MODERATE (MDT)	5 - HIGH (HIGH)
No severe* thunderstorms expected	Isolated severe thunderstorms possible	Scattered severe storms possible	Numerous severe storms possible	Widespread severe storms likely	Widespread severe storms expected
Lightning/flooding threats exist with <u>all</u> thunderstorms	Limited in duration and/or coverage and/or intensity	Short-lived and/or not widespread, isolated intense storms possible	More persistent and/or widespread, a few intense	Long-lived, widespread and intense	Long-lived, very widespread and particularly intense
					
<ul style="list-style-type: none"> • Winds to 40 mph • Small hail 	<ul style="list-style-type: none"> • Winds 40-60 mph • Hail up to 1" • Low tornado risk 	<ul style="list-style-type: none"> • One or two tornadoes • Reports of strong winds/wind damage • Hail ~1", isolated 2" 	<ul style="list-style-type: none"> • A few tornadoes • Several reports of wind damage • Damaging hail, 1 - 2" 	<ul style="list-style-type: none"> • Strong tornadoes • Widespread wind damage • Destructive hail, 2" + 	<ul style="list-style-type: none"> • Tornado outbreak • Derecho

* NWS defines a severe thunderstorm as measured wind gusts to at least 58 mph, and/or hail to at least one inch in diameter, and/or a tornado. All thunderstorm categories imply lightning and the potential for flooding. Categories are also tied to the probability of a severe weather event within 25 miles of your location.

What Makes a Storm Severe?

- Wind gusts of 58 MPH or greater, and/or
- Hail 1 inch or more in diameter

Severe Thunderstorm Warning is issued for potential of this occurring, or if observed



- A tornado also makes a storm severe

Tornado Warning is issued for potential of this occurring, or if observed



Lightning does not make a thunderstorm severe

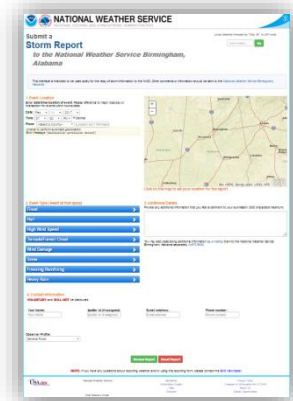
Reporting Options Recap

- Call the NWS office: 205-664-3010, option 2
- Social media: Twitter, Facebook
- Our webpage: 'Submit a Storm Report' page
- Photos of what you're seeing/detailed follow-up are great, too!

sr-dss.bmx@noaa.gov

- Snapshot of a funnel, wall cloud, flooding, etc.
- Hail, wind damage (trees, buildings, etc.)

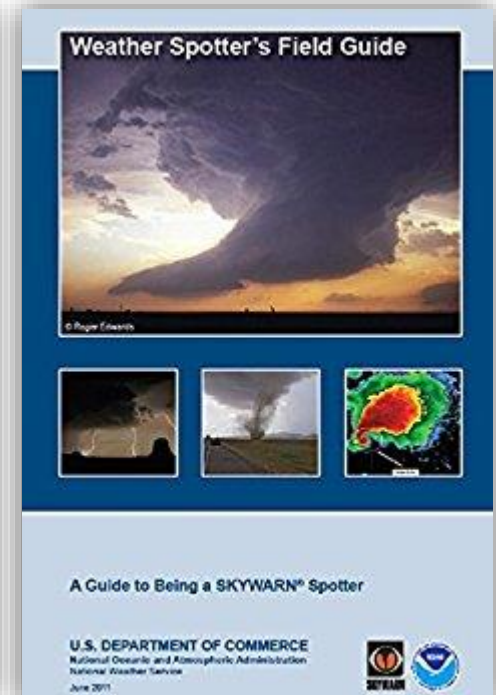
Don't use e-mail for urgent reports!



Additional Materials

Visit our Skywarn spotter page for useful links and information: weather.gov/bmx/skywarnschedule

- Advanced spotter certificates
www.weather.gov/bmx/advancedspottertraining
- Spotter schedule
- Training materials
- Brochures and guides



SKYWARN *Advanced* **Training**

Gerald Satterwhite
Meteorologist

U.S. Department of Commerce
National Oceanic and Atmospheric Administration (NOAA)
National Weather Service (NWS) – Calera, AL

Questions, Suggestions, or Comments?
Gerald.Satterwhite@noaa.gov

We thank you for your participation!
Keep your eye in the sky!

